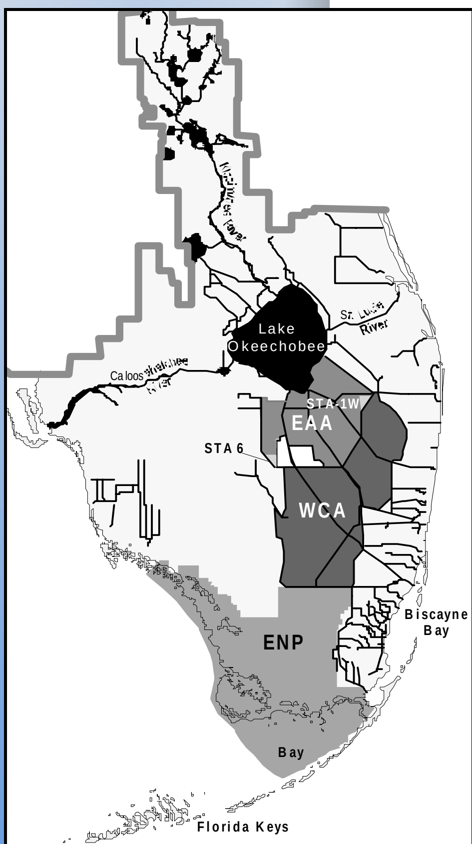
Water Quality Conditions Quarterly Report

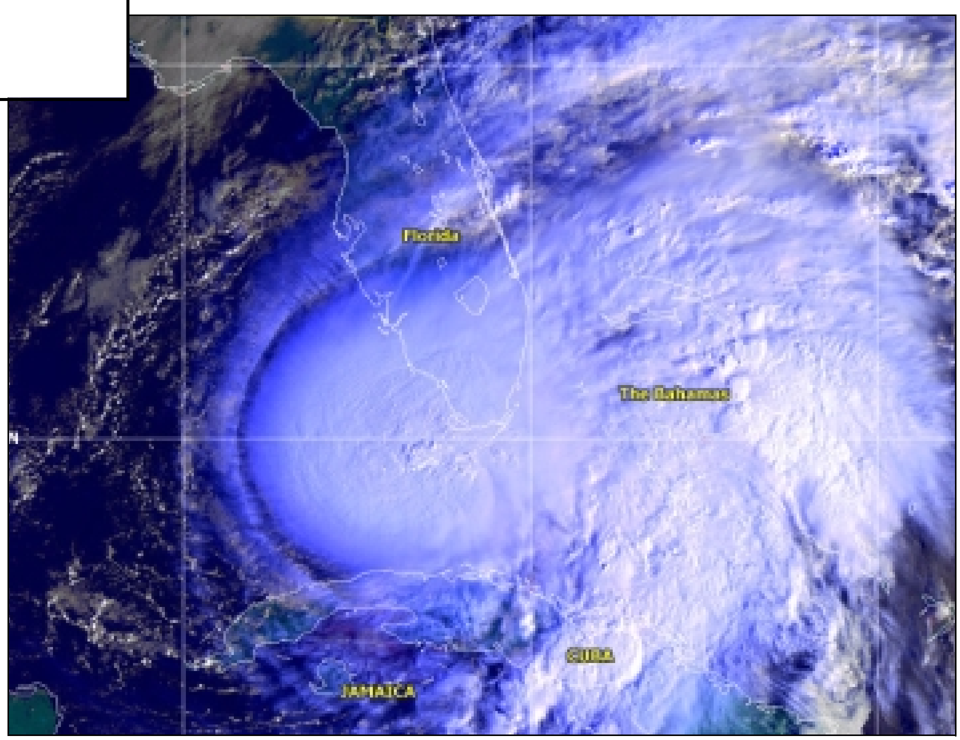
ENVIRONMENTAL MONITORING AND ASSESSMENT DEPARTMENT
SOUTH FLORIDA WATER MANAGEMENT DISTRICT • April 2000



This issue analyzes water quality and hydrologic data collected from October through December 1999. Hurricane Irene was the significant meteorological event of the fourth quarter, making landfall on the southwestern coast of the Everglades National Park during the late afternoon of Oct.15. As a result of the hurricane, South Florida experienced the second wettest October in 30 years. Lake Okeechobee and the water conservation areas (WCAs) received high loads of total phosphorus in the resulting stormwater runoff. Total phosphorus concentrations in Lake Okeechobee increased to over 200 ppb in 30 percent of the lake surface area due to stormwater discharges into the lake, scheduled water releases from Lake Kissimmee, and resuspension of phosphorus rich lake sediments. These conditions resulted in high lake turbidity levels and average total phosphorus concentrations greater than 180 ppb that remained in lake surface waters through the end of the year. The phosphorus load in EAA runoff to the WCAs resulted in a load of 53 metric tons in October. Peak flows in most canals occurred within a day or two after the storm, but above average flows continued to be discharged from the marshes of Water Conservation Area 3 into Everglades National Park through December.

Highlighted above are the major areas within the South Florida Water Management District covered in this report.

Photo at Right: Satellite Image of Hurricane Irene, October 15, 1999. Courtesy of NOAA.



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Rainfall

Hurricane Irene provided South Florida with the single largest volume of rainfall in the fourth quarter of 1999. The eye of Hurricane Irene made landfall in the western part of Everglades National Park at approximately 2:30 p.m. on Oct. 15 (satellite image on the front page of this report). The eye of the storm shifted to the northeast at 7 p.m., moving over Water Conservation Areas 3 and 2 and the Loxahatchee National Wildlife Refuge. The eye then took a turn to the north and moved offshore near Jensen Beach at approximately 2:30 a.m. on Oct. 16. Areas receiving the heaviest rainfall were to the east of Irene's path. The five areas with the heaviest rainfall from Oct. 14 - 16 were: Everglades National Park, 11.61 inches; Water Conservation Area 3, 9.19 inches; Palm Beach County, 8.53 inches; Broward County, 8.13 inches and Miami-Dade County, 7.98 inches.

Rainfall

Monthly total rainfall for 1999 in various rainfall basins and stormwater treatment areas is presented in **Table 1**. The monthly rainfall totals are weighted averages of available data from rainfall gages reported in the District daily rainfall report compiled by Water Resources Operations and from other agencies collecting rainfall data in South Florida.

Historically, the occurrence of rainfall in South Florida during the dry months (November through April) has been generally associated with occasional disturbances such as cold fronts, and during the wet months (June through September) attributed to frequent thunderstorms. May and October have been considered transitional months and can be either dry or wet.

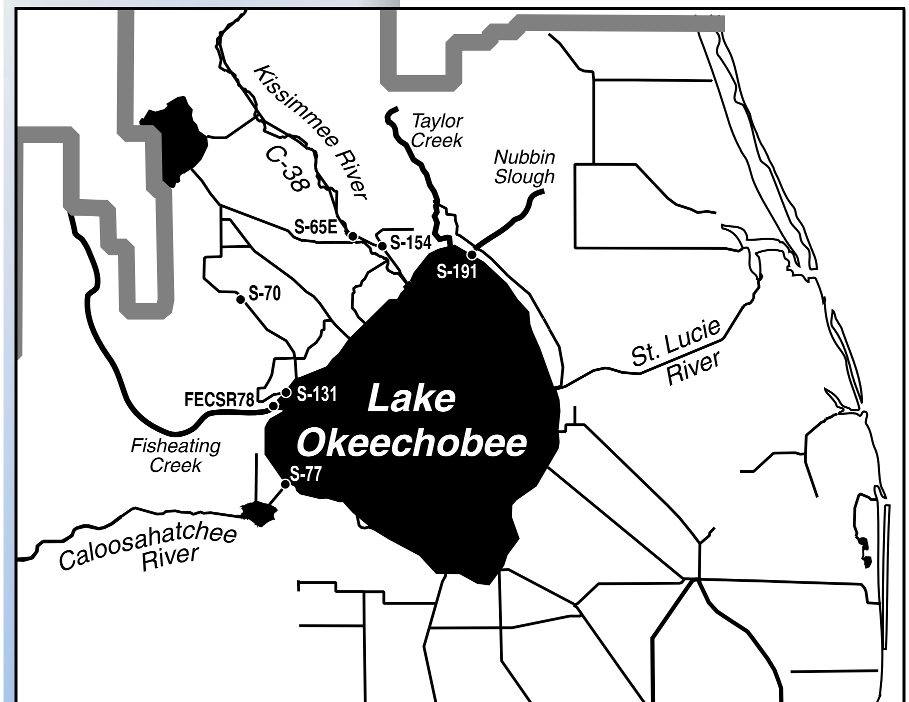
Heavy precipitation from Hurricane Irene dominated the rainfall in the fourth quarter of 1999. From the early morning of Oct. 14 through the morning of Oct. 16, Irene delivered heavy rainfall to the southeastern sections of South Florida. Everglades National Park received 11.61 inches and Water Conservation Area 3 received 9.19 inches. Palm Beach County, Broward County and Miami-Dade County had 8.53, 8.13 and 7.98 inches of rainfall, respectively. Overall, Irene made October 1999 the second wettest October in 30 years. The 1999 wet season, June through October, ended as the second wettest since 1960 at 43.09 inches or 131 percent of the historic average. November and December, in contrast, had District-wide rainfalls that were both 60 percent of their respective monthly historical averages.

Table 1. Monthly Thiessen Weighted Rainfall Averages (inches)

Rainfall Basin	Jan-99	Feb-99	Mar-99	Apr-99	May-99	Jun-99	Jul-99	Aug-99	Sep-99	Oct-99	Nov-99	Dec-99	Total
Upper Kissimmee	2.9	1.0	0.8	2.5	4.3	10.0	2.5	7.7	6.4	6.0	2.5	2.5	49.1
Lower Kissimmee	2.1	0.4	0.5	2.4	3.6	11.6	3.9	8.4	7.0	6.1	0.9	1.7	48.6
Lake Okeechobee	2.6	0.3	0.6	2.4	3.7	12.5	5.1	7.4	7.4	5.3	0.5	1.1	48.9
east EAA	2.3	1.0	0.5	1.1	4.4	11.9	5.5	5.1	9.2	7.8	0.6	0.6	50.0
west EAA	2.2	0.7	0.6	1.0	5.8	15.0	6.9	8.9	13.1	7.4	1.0	0.4	63.0
WCAs 1&2	3.3	2.3	0.5	1.3	2.9	17.1	3.2	7.5	8.6	12.4	1.3	0.8	61.2
WCA 3	2.4	1.1	0.3	1.6	3.7	13.3	4.5	8.1	9.5	13.0	1.7	0.6	59.8
ENP	0.0	0.1	0.0	1.2	4.8	12.3	12.8	12.1	8.4	*15.3*	***1.1***	***0.8***	***68.9***
C111 Basin	0.0	0.0	0.0	1.1	5.9	10.1	0.00	3.9	2.4	13.3	1.5	1.2	39.4
STA-1W	2.2	0.6	0.7	1.2	2.7	12.1	2.5	5.7	6.1	12.1	0.3	0.9	47.1
STA6	0.0	0.2	0.0	0.8	11.0	14.9	4.8	9.5	3.4	11.1	1.1	0.4	57.2

Bolded values are based on estimated average rainfall from nearby rain gauges, (CHEKIKA EVER. and S-332R).

Lake Okeechobee Drainage Basin



Approximately 239 metric tons of phosphorus entered Lake Okeechobee during the fourth quarter of 1999. Roughly 86 percent of this load occurred in October. The high load in October resulted from Hurricane Irene and scheduled freshwater releases from Lake Kissimmee. Phosphorus concentrations, light penetration and chlorophyll a *levels in the lake were also affected by the hurricane. During November and December 1999, in-lake phosphorus concentrations averaged 190 and 184 ppb, respectively. Light penetration was generally limited to the upper 0.4 meters of the water column. As a result of poor light penetration in the lake, chlorophyll* a *levels in the lake averaged less than 25 ppb during the fourth quarter of 1999.*

Phosphorus Loading and Rainfall Trends

Monthly rainfall in the Lake Okeechobee drainage basin and total phosphorus loads and flows to the lake over a 27-month period are presented in **Figure 1**. Phosphorus loads were calculated by multiplying concentration data and flow data measured at 26 monitoring stations that discharge into Lake Okeechobee.

Monthly rainfall (**Figure 1)** is presented as area-weighted rainfall averages from a network of meteorological stations in the Upper Kissimmee, Lower Kissimmee and Lake Okeechobee basins. The mean rainfall recorded for these three basins was 5.8, 1.3 and 1.8 inches for October, November and December, respectively (**Figure 1)**.

Phosphorus loads to the lake generally exhibit a seasonal trend. Higher loads typically occur during wetter months, while lower loads occur during drier months of the year. However, climatic disturbances, such as El Niño (December 1997 - April 1998) and tropical storms (November 1998), can alter this seasonal distribution of phosphorus to the lake (**Figure 1)**.

During the last quarter of 1999, approximately 239 metric tons of phosphorus entered Lake Okeechobee (**Figure 1)**. Roughly 86 percent (or 205 metric tons) of this quarterly phosphorus load entered the lake in October. The two major contributing structures were S-191 and S-65E .

On Oct.15, 1999, Hurricane Irene passed across the southeastern portion of Lake Okeechobee. Rainfall and associated runoff from Hurricane Irene contributed approximately 74 metric tons of phosphorus primarily through S-191. Conversely, 65 metric tons of phosphorus, which entered the lake in October through S65E, were not believed to have resulted from the hurricane. Scheduled releases of water to maintain appropriate water levels in Lake Kissimmee resulted in the observed phosphorus input to the Lake Okeechobee.

Phosphorus loads for November and December loads were 21 and 12 metric tons respectively, and accounted for only 14 percent of the total load for the fourth quarter of 1999.

Phosphorus Concentrations in the Tributaries/Basins

The phosphorus concentration target for each basin was established under the 1989 Interim Surface Water Improvement and Management (SWIM) Plan. This target was

Monthly Total Phosphorus Loading, Rainfall and Flow

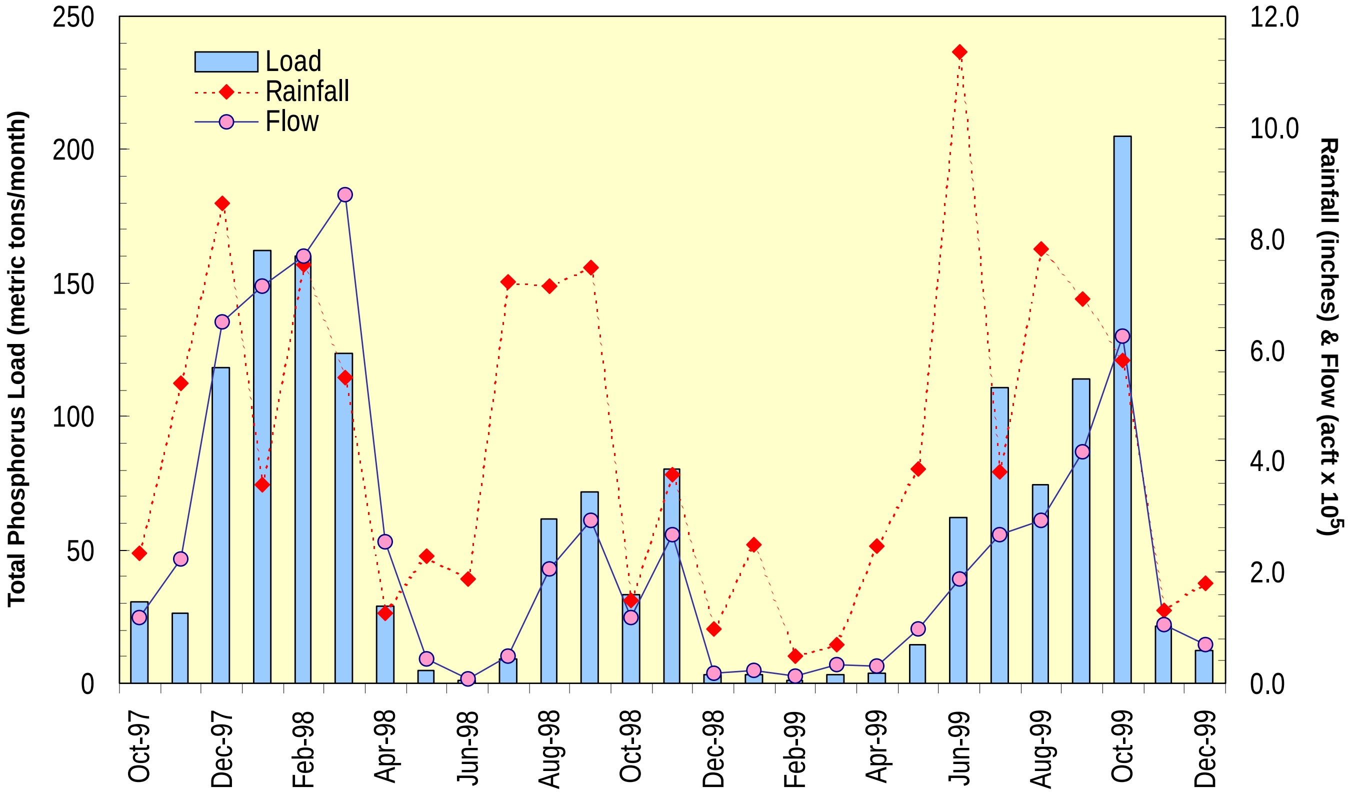


Figure 1. Monthly total phosphorus loads, rainfall and flow for Lake Okeechobee.

incorporated to ensure a reduction in phosphorus loads to Lake Okeechobee. Under this SWIM Plan, the phosphorus concentration in each basin must either be below 180 parts per billion (ppb) or at the 1989-discharge concentration (whichever is less).

Flow-weighted mean concentrations of total phosphorus from four of the 39 basins that drain into Lake Okeechobee were used to calculate the 12-month moving average concentrations shown in **Figure 2**. Kissimmee River, S-154, Fisheating Creek and Taylor Creek/ Nubbin Slough Basins are major contributors of phosphorus load into the lake. These 12-month moving average concentrations are compared to their respective targets (**Figure 2)**.

Since May 1991, 12-month moving average phosphorus concentrations for the Kissimmee River Basin have consistently been below the target concentration of 180 ppb (**Figure 2a**). However, 12-month moving average phosphorus concentrations for the S-154 Basin and Taylor Creek Nubbin Slough have been consistently above the target level.

The 12-month moving average phosphorus concentrations for Fisheating Creek have periodically been below the target level. From October 1996 through September 1999, the 12-month moving average phosphorus concentration in the creek has been consistently above the target concentration of 180 ppb (**Figure 2b**). During the fourth quarter of 1999, the 12-month moving average phosphorus concentration in Fisheating Creek was below the target limit.

The 12-month moving average phosphorus concentrations from the S-154 Basin remained relatively constant during the fourth quarter of 1999 and approximately 20 percent lower than for the previous quarter. Nevertheless, the 12-month moving average phosphorus concentrations remained above the target level (**Figure 2a**).

The effects of rainfall from Hurricane Irene can be observed in the increased phosphorus concentrations for the Taylor Creek/ Nubbin Slough Basin during the fourth quarter (**Figure 2b**). The 12-month moving average concentrations increased by approximately 120 ppb from the previous quarter.

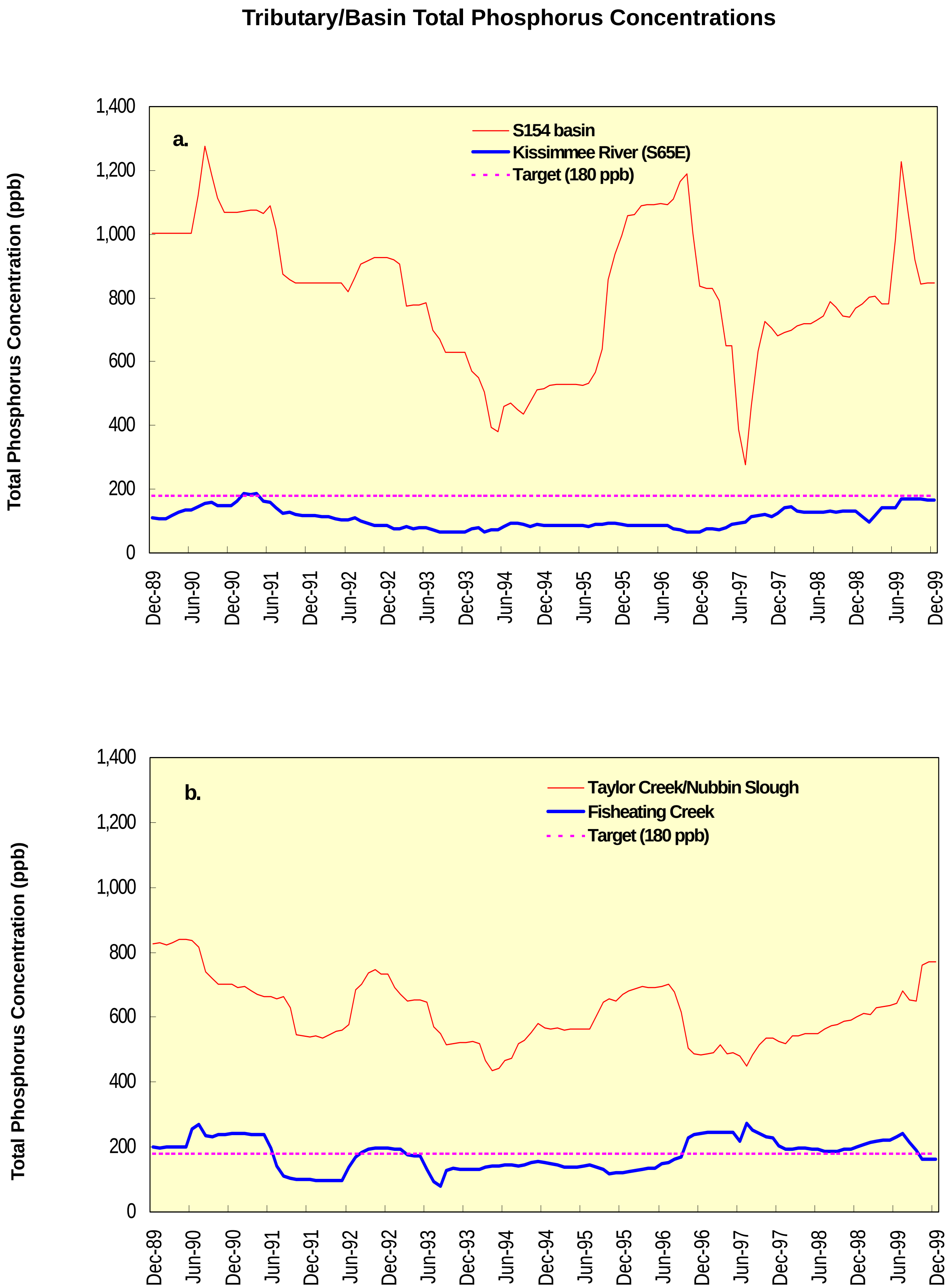


Figure 2. Twelve-month moving flow-weighted mean total phosphorus concentrations for: **a.** Kissimmee River and S154 Basins and **b.** Taylor Creek/ Nubbin Slough and Fisheating Creek. The four basins/tributaries drain into Lake Okeechobee.

Long-Term Analysis

A long-term analysis of phosphorus loads is provided as a 5-year moving average calculated at the end of each calendar year. These averages are calculated for actual and target phosphorus loads. The actual load consists of the inflow from tributaries to the lake each year plus an assumed contribution from atmospheric deposition of 64.4 metric tons per year (**Figure 3**). The target load is calculated using the modified Vollenweieder model. The difference between the target and actual loads is referred to as the ***over-target load*** and is presented in **Figure 4**. The actual, target, over-target and 5-year moving average loads are summarized in **Table 2** for the period from 1973 through 1999.

Over the past decade, several programs have been implemented to reduce phosphorus loads to Lake Okeechobee. These programs include best management practices (BMPs), dairy buy-outs, regulatory programs for non-dairy uses of land, and limited back pumping to the lake from the Everglades Agricultural Area (EAA). It is apparent that these programs by themselves will not be sufficient to achieve the required in-lake concentration and associated load reduction and, therefore, must be supplemented with other load reduction measures. The Lake Okeechobee Water Retention/ Phosphorus Removal Critical Restoration Project has been developed to increase regional water storage north of Lake Okeechobee by on-site wetland restoration and water retention, with a secondary benefit of reducing phosphorus in surface runoff. Currently, 12 potential sites have been identified. Two are for proposed stormwater treatment (attenuation) facilities, which the U.S. Army Corps of Engineers will design and construct. At the other 10 sites, the District has proposed to design and construct modifications to improve stormwater retention, restore wetlands and improve the quality of discharged water. These proposed project sites are located throughout the northern Lake Okeechobee watershed, in the lower Kissimmee River Basins (S-65D and S-65E), S-154, and the Taylor Creek-Nubbin Slough Basins (S-191).

Total Phosphorus Concentrations

Lake Okeechobee has a long history of excessive phosphorus loading, and this has resulted in major changes in the ecosystem, including an increased frequency of algal blooms, dominance by blue-green algae, and the accumulation of over 30,000 metric tons of phosphorus in the lake sediments. From the early 1970s, to the 1990s, total phosphorus concentrations in the lake's water column increased from below 50 ppb to over 100 ppb. This range may be the result of resuspension and settling of the phosphorus-rich lake sediments, caused by wind and waves. The District and other agencies have initiated an aggressive program to further reduce external phosphorus loads to the lake, and are conducting a feasibility study to determine the ecological, engineering and economic implications of removing all or part of the phosphorus-rich mud sediments.

In order to assess the seasonal and spatial variations in phosphorus concentrations in the lake resulting from inputs as well as internal cycling, distribution plots of open-water total phosphorus concentrations are presented in **Figures 5a** through **5c**.

Hurricane Irene did not affect October water quality data collected at in-lake stations because sampling occurred several days before the hurricane moved through the area. During October 1999, the arithmetic average of surface water phosphorus concentrations in Lake Okeechobee was 94 ppb. The contour plot of total phosphorus concentrations in the lake (**Figure 5a**) shows more than 75 percent of the lake's surface waters had phosphorus concentrations greater than 80 ppb. Of this area, the highest concentrations were found in the center of the lake. Approximately 1 percent of the lake's area had concentrations greater than 160 ppb and was located near the mouth of the Kissimmee River.

Contour plots for November and December show dramatically higher phosphorus concentrations across the lake (**Figures 5b** and **5c**). Approximately 98 percent of Lake Okeechobee had phosphorus concentrations greater than 80 ppb. Concentrations greater than 200 ppb covered more than 30 percent of the lake. These higher phosphorus levels extended from the mouth of the Kissimmee River toward the central portion of the lake (**Figure 5b**). During November, phosphorus concentrations in the surface water of the lake averaged 190 ppb.

By December, phosphorus concentrations in Lake Okeechobee decreased slightly to an average of 184 ppb. Nevertheless, phosphorus concentrations exceeding 200 ppb covered approximately 35 percent of the lake. This area of high phosphorus concentration was located in the central portion of the lake and stretched from Fisheating Bay toward the eastern shore. All of the lake phosphorus concentrations measured in December 1999 were greater than 80 ppb.

The high phosphorus concentrations observed during both November and December were a result of runoff inputs and hurricane wind-driven resuspension of sediments. The thickness of the mud layer ranges from 10 to 80 cm. The upper 10 to 15 cm of the sediments can be resuspended easily. Because the sediments in the lake are fine-grained and phosphorus-rich, any resuspension will result in elevated phosphorus levels. Resuspension occurs primarily in the central portion of the lake. Resuspension in the lake is supported by the relationship between turbidity (or amount of suspended material) and phosphorus concentrations during the fourth quarter of 1999 (**Figure 6**).

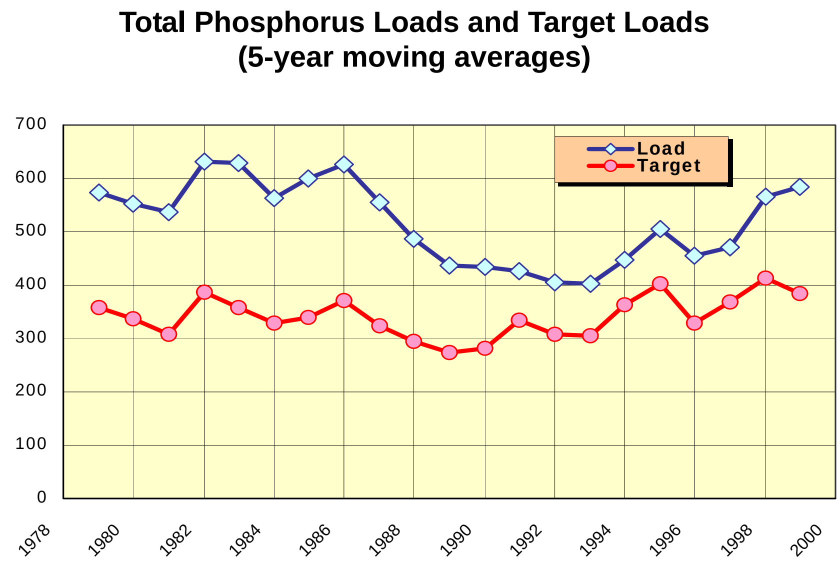


Figure 3. Comparison of the actual load to the target load. Data are 5-year moving averages.

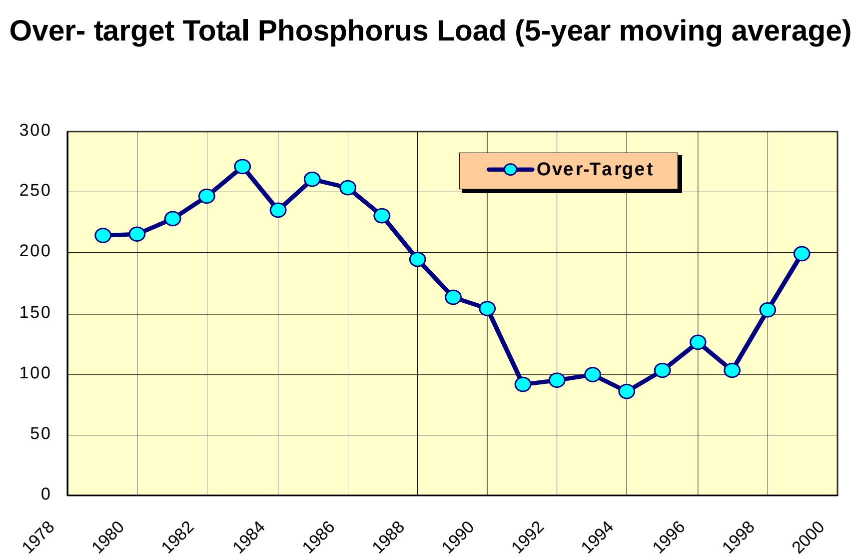


Figure 4. The 5-year moving average of over-target loading to Lake Okeechobee. This data is the difference between the actual load and the target load depicted in the figure above.

Table 2. Historic Total Phosphorus Loading Data

Year	Actual Load (metric ton)	Target Load (metric ton)	Annual Over-Target (metric ton)	Long-Term Over-Target (5-yr moving average)
1973	499	476	23	
1974	802	413	388	
1975	361	266	95	
1976	467	285	183	
1977	397	257	140	166
1978	672	544	129	187
1979	965	441	524	214
1980	258	157	101	215
1981	388	138	250	229
1982	879	647	232	247
1983	659	410	249	271
1984	633	288	345	235
1985	435	211	225	260
1986	521	303	218	254
1987	525	410	115	230
1988	325	256	69	194
1989	379	191	188	163
1990	425	247	178	154
1991	474	570	-96	91
1992	418	280	137	95
1993	323	232	90	100
1994	604	488	116	85
1995	707	440	267	103
1996	225	205	20	126
1997	492	472	20	103
1998	804	463	341	153
1999	691	341	349	200

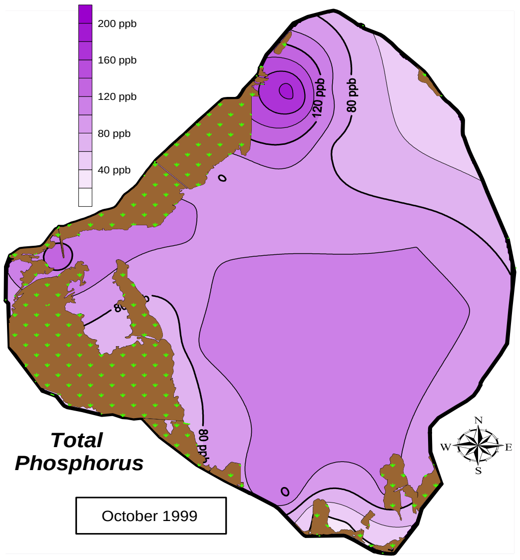


Figure 5a. Total phosphorus concentrations for open water monitoring sites in Lake Okeechobee, October 1999.

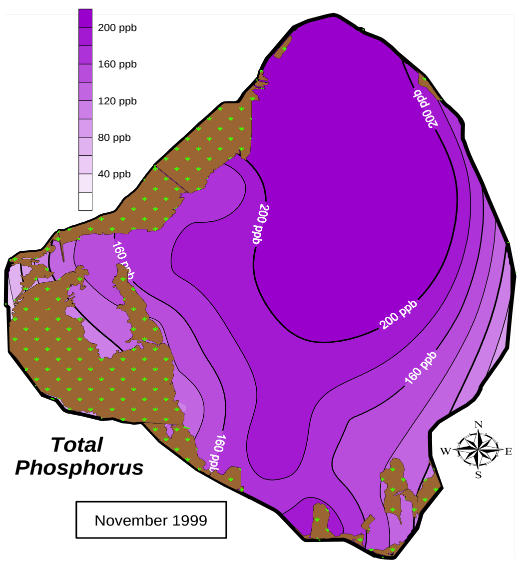


Figure 5b. Total phosphorus concentrations for open water monitoring sites in Lake Okeechobee, November 1999.

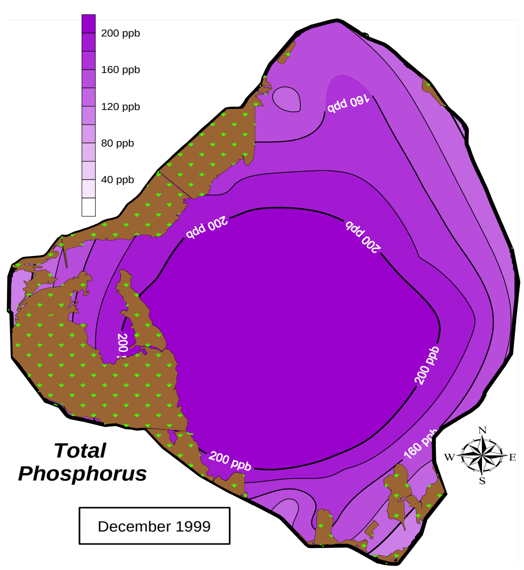


Figure 5c. Total phosphorus concentrations for open water monitoring sites in Lake Okeechobee, December 1999.

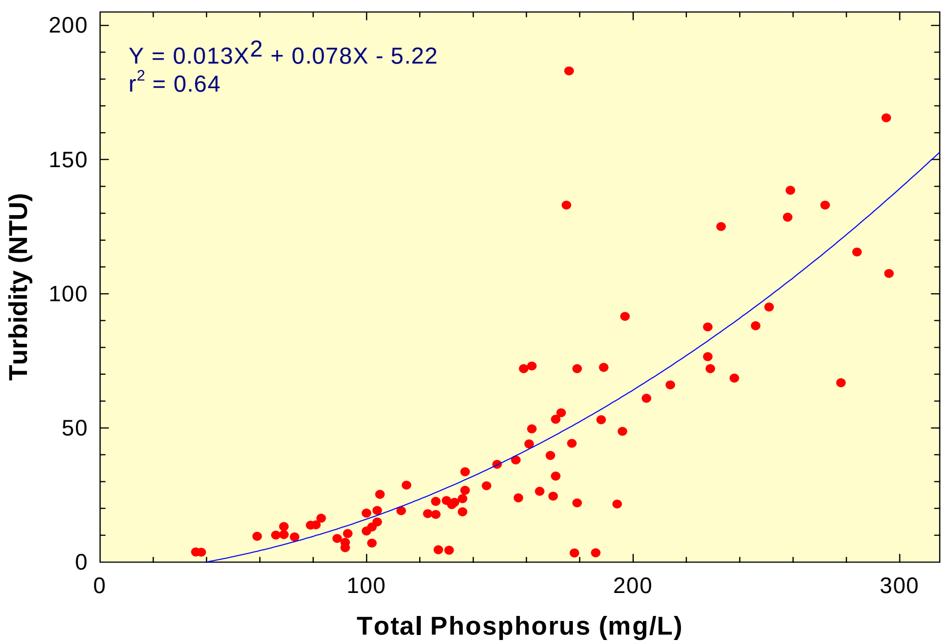


Figure 6. Relationship of total phosphorus concentration with turbidity in Lake Okeechobee during the fourth quarter of 1999.

Light Penetration

Secchi depth is a measure of how deep light penetrates the water column. The Secchi depth is measured by lowering a 30-cm diameter white disk through the water column until it is just visible. At the Secchi depth, solar light penetrating the water is reflected off the surface of the disk in a quantity just sufficient to come back through the water and reach the observer's eye. The depth to which light will penetrate is affected by the amount of suspended material and dissolved colored substances in the water column. When either of these two variables is high, light will not penetrate deeply into the water column (i.e., Secchi depth decreases).

The transmission of light in lakes and other water bodies is extremely important because solar radiation is the primary source of energy for photosynthetic organisms like algae. An increase in light penetration can cause increased photosynthetic activity, resulting in higher primary productivity, if nutrients are not limiting.

During the fourth quarter of 1999, Secchi depths averaged 0.4 meters in October, and 0.2 meters in November and December. Contour plots showing the Secchi depths for these three months are provided in **Figures 7a** through **7c**.

Light penetration in Lake Okeechobee extended down to a maximum depth of 0.7 meters during the October 1999 monitoring event (**Figure 7a**), which occurred prior to Hurricane Irene. Over approximately 50 percent of the lake, light penetrated to less than 0.4 meters in depth.

As a result of turbulent mixing in the lake associated with the hurricane, light penetration less than 0.4 meters occurred over more than 80 percent of the lake during both November and December.

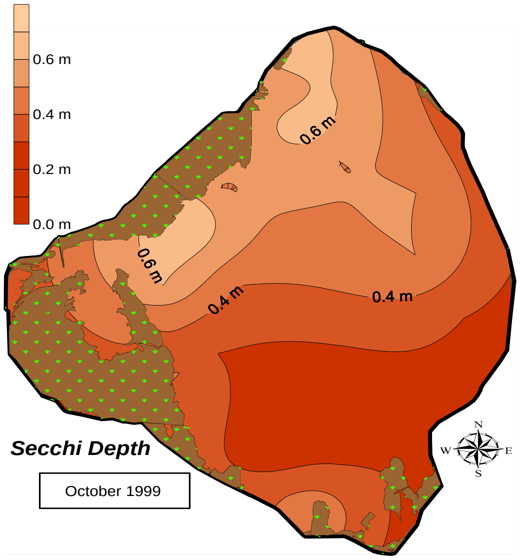


Figure 7a. Depth of light penetration (Secchi depth) measured in meters for Lake Okeechobee.

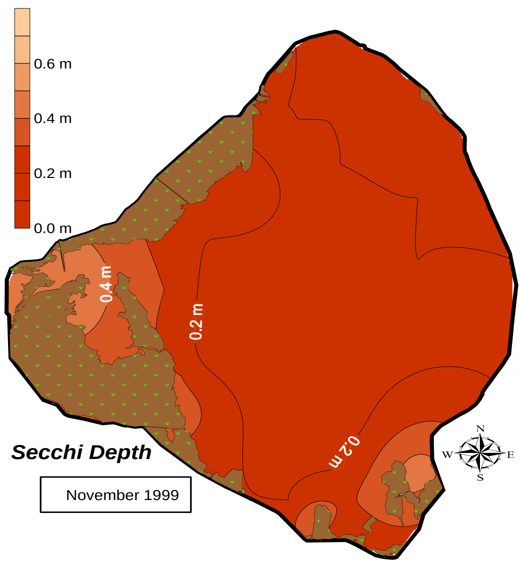


Figure 7b. Depth of light penetration (Secchi depth) measured in meters for Lake Okeechobee.

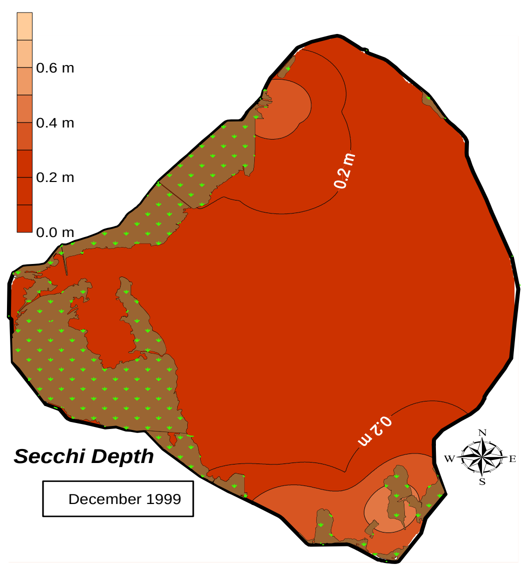


Figure 7c. Depth of light penetration (Secchi depth) measured in meters for Lake Okeechobee.

Chlorophyll *a* Concentrations

Chlorophyll *a* is a green pigment present in terrestrial and aquatic plants, including algae. This pigment functions to absorb visible light. The energy associated with the absorbed light is used to drive photosynthesis. Chlorophyll *a* concentrations are an indicator of the amount of living plant (or algal) material in a water body.

Naturally occurring algal populations present in Lake Okeechobee will form blooms under certain weather and water quality conditions.

Algal blooms are dense concentrations of algae over large areas of a water body. Blooms may be composed of undesirable species that are harmful to other aquatic life, may form nuisance mats on the water surface, and create taste and odor in the drinking water supply. If algal populations are large enough, they can also reduce oxygen levels in the water column during algal die-off resulting in invertebrate and fish kills.

Severe bloom conditions generally occur when chlorophyll *a* concentrations exceed 60 ppb. Concentrations between 40 and 60 ppb are indicative of moderate bloom conditions. The occurrence and effects of these bloom conditions on the lake depend on a variety of factors. Persistence of bloom conditions over large areas may indicate increased nutrient concentrations.

Lake-wide chlorophyll *a* distributions at open water monitoring stations for October 1999 through December 1999 are presented in **Figures 8a** through **8c**. During these three months, mean chlorophyll *a* levels in Lake Okeechobee ranged from 10 ppb in December to 23 ppb in October. These levels are lower than those reported during the same period in 1998.

Moderate and severe bloom conditions existed in the lake only during the October (or pre-Hurricane Irene) event (**Figure 8c**). Less than 1 percent of the surface water of the lake exhibited severe bloom conditions with approximately 10 percent exhibiting moderate bloom conditions. These blooms occurred in the western portion of the lake within Fisheating Bay.

No bloom conditions were observed in the lake for the two months (November and December) following Hurricane Irene (**Figure 8b** and **8c**). Although phosphorus concentrations reported for the lake after the hurricane were relatively high, chlorophyll *a* concentrations steadily decreased. The growth of algal material during November and December 1999 was probably limited by the amount of light that could penetrate the water column. Because of sediment resuspension, light penetration was reduced resulting in lower photosynthetic activity in the water column.

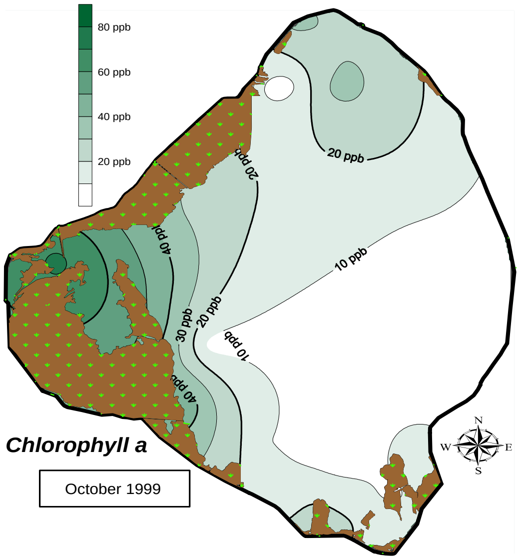


Figure 8a. Chlorophyll *a* levels at open water monitoring sites in Lake Okeechobee, October 1999.

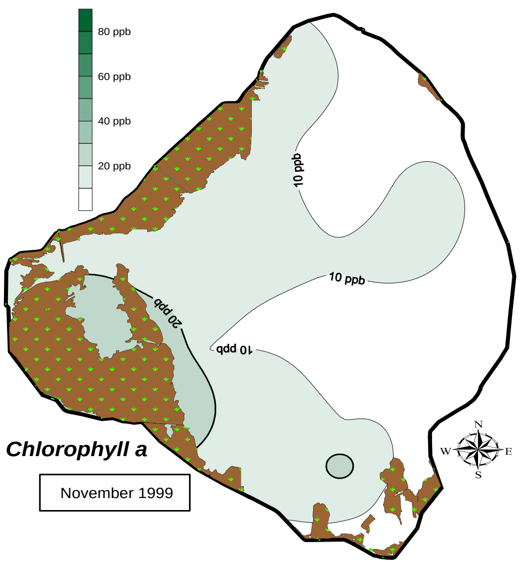


Figure 8b. Chlorophyll *a* levels at open water monitoring sites in Lake Okeechobee, November 1999.

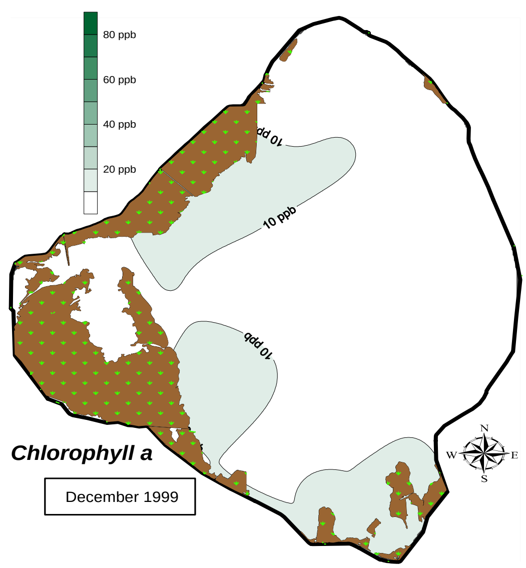
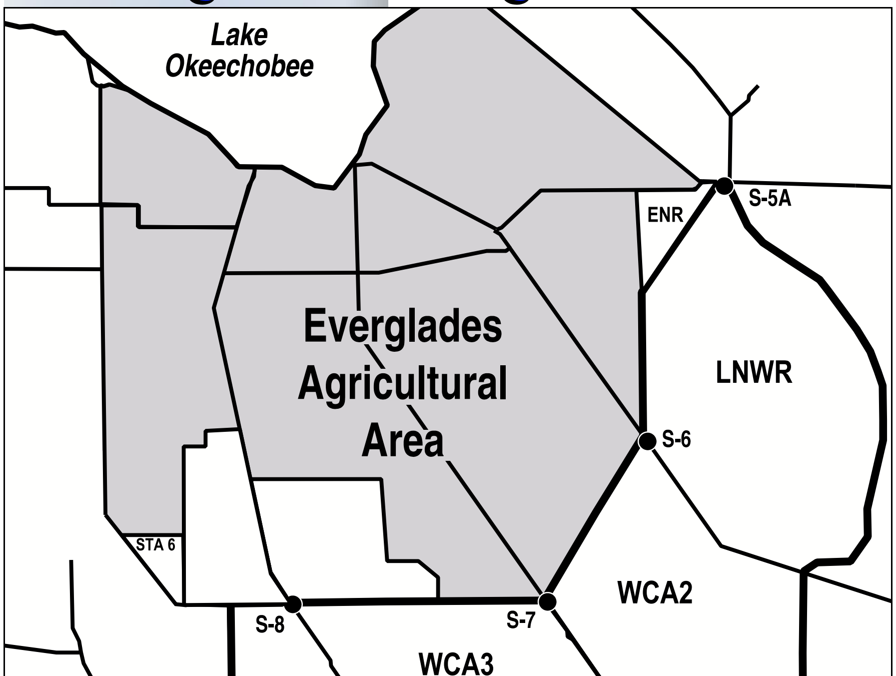


Figure 8c. Chlorophyll *a* levels at open water monitoring sites in Lake Okeechobee, December 1999.

Everglades Agricultural Area



Hurricane Irene contributed 5.9 inches of rainfall to the EAA Basin in a three day period from October 14 through 16. This resulted in the highest monthly total phosphorus load (54 metric tons) discharged from the EAA Basin during the 1999 calendar year. Overall, the fourth quarter of 1999 was relatively dry for the EAA with 11.4 inches of total rainfall and the TP load contribution of 57 metric tons.

Phosphorus Loading Trends

The Everglades Best Management Practice (BMP) Program (Rule 40-E, 63, Florida Administrative Code) for the Everglades Agricultural Area (EAA) requires that the EAA Basin achieve a 25 percent reduction in total phosphorus (TP) load discharged to the Everglades. This reduction is determined by comparing phosphorus discharges at the end of each water year (May 1 through April 30) with the rainfall-adjusted, pre-BMP base period of Oct. 1, 1978, through Sept. 30, 1988. The area has been in compliance since the first full year of BMP implementation (water year 1996).

Total phosphorus concentrations discharged from the EAA Basin during the fourth quarter were generally lower than the previous quarter in 1999. However, the Hurricane Irene storm event contributed 5.9 inches of rainfall to the EAA Basin in three days (October 14 through 16). This rainfall resulted in the largest monthly flow (367 thousand acre-feet) and the largest monthly phosphorus load (54 metric tons) observed during the 1999 calendar year (**Figure 9**). This is similar to what happened during the fourth quarter in 1998. Tropical storm Mitch contributed 9.0 inches of rainfall to the EAA Basin in two days (November 4 and 5) while the quarter, as a whole, was relatively dry with a total rainfall of 12.4 inches. The total rainfall of 9.6 inces for November 1998 resulted in the largest monthly flow (340 thousand acre-feet) and the largest monthly phosphorus load (73 metric tons) observed during the 1998 calendar year (**Figure 9**).

The fourth quarter, as a whole, was relatively dry again this year. After receiving 9.2 inches of rainfall in October, the EAA Basin only received 1.5 and 0.7 inches of rainfall, and discharged 44 and 12 thousand acre-feet of flow in November and December, respectively. The corresponding TP load for November was only 6 metric tons due to the low rainfall, flow and TP concentrations. The calculated TP load for December was -3 metric ton, meaning that the TP outflow from the EAA Basin was lower than the TP inflow into the basin (**Figure 9**).

Total phosphorus concentrations and flow are measured at pump stations S-5A, S-6, S-7 and S-8 (see map). The majority of the water from the EAA is transported to the water conservation areas (WCAs) through these pump stations. Flows through these structures, as well as the calculated total phosphorus loads, are shown in **Figure 10**. Flow-weighted mean total phosphorus concentrations entering the WCAs at these stations are

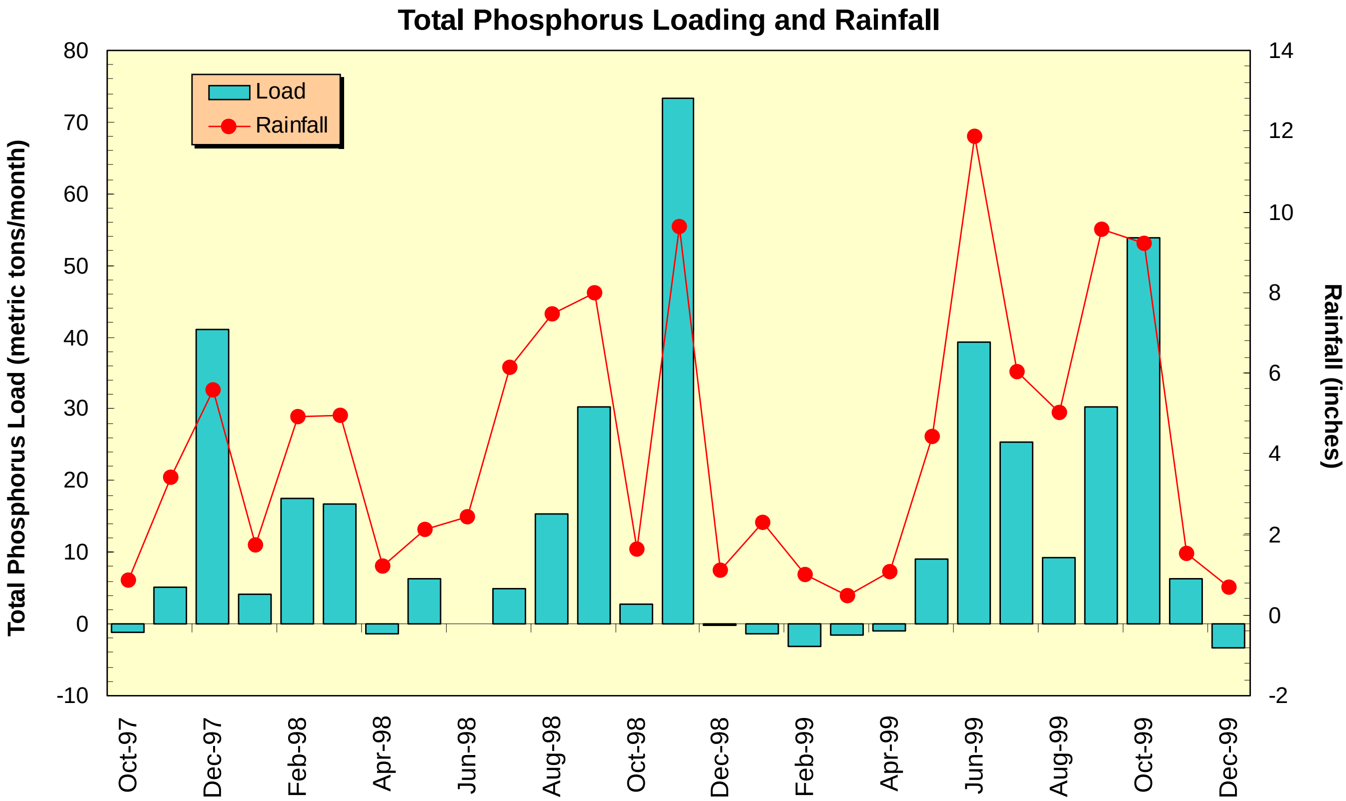


Figure 9. Monthly phosphorus loads calculated for the EAA Basin and monthly rainfall for the EAA

presented in **Figure 11**. All four pump stations had highest flow in October during 1999. The flow at the four sites dropped rapidly after the storm events passed and had very low flow through December (**Table 3**). Historically, S-5A had the highest TP concentrations and loads even though S8 had the highest flow of the four pump stations (**Table 4**). The S-8 structure had very high flow in October, resulting in the highest TP loads for the quarter among the four stations. Flow weighted TP concentrations for all four pump stations were lower than the high peaks observed during the preceding wet season and they were highest in November during the fourth quarter except for S-8.

Total inflow from Lake Okeechobee to the EAA Basin through S-351 and S-354 for the quarter was 109 thousand acre-feet. In October, 29 thousand acre-feet of water and 9 metric tons of TP were back-pumped into the lake at S-2. There was no back-pumping in November and in December at S-2. At S-3, 3 thousand acre-feet of water and 0.5 metric tons of TP were back-pumped in October. There was no back-pumping in November and only a negligible amount in December at S-3. There was no back flow into the Lake at S-352 during the quarter.

Table 3. EAA Pump Station Flows (kac-ft)

	Oct-99	Nov-99	Dec-99
S5A	105	24	33
S6	74	16	20
S7	64	7	1
S8	135	12	0
Total	**379**	**59**	**53**

Table 4. EAA Pump Station Loads (metric tons/month)

	Oct-99	Nov-99	Dec-99
S5A	16	4	5
S6	13	2	2
S7	4	0	0
S8	21	2	0
Total	**53**	**9**	**8**

Table 5. EAA Pump Station Flow-weighted Mean Concentrations (ppb)

	Oct-99	Nov-99	Dec-99
S5A	124	150	137
S6	137	90	90
S7	49	56	29
S8	123	146	

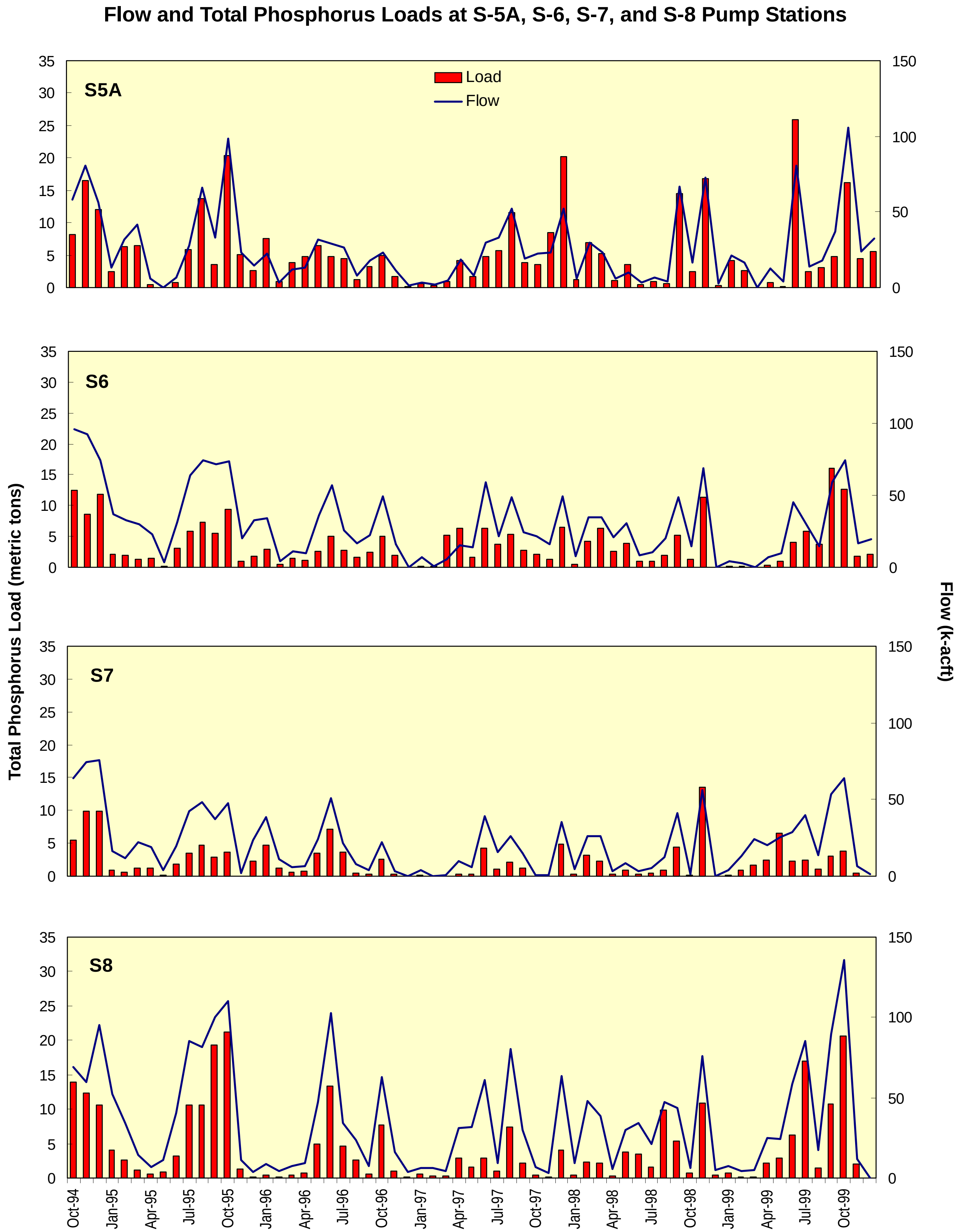


Figure 10. Monthly flows and calculated phosphorus loads at major EAA pump stations.

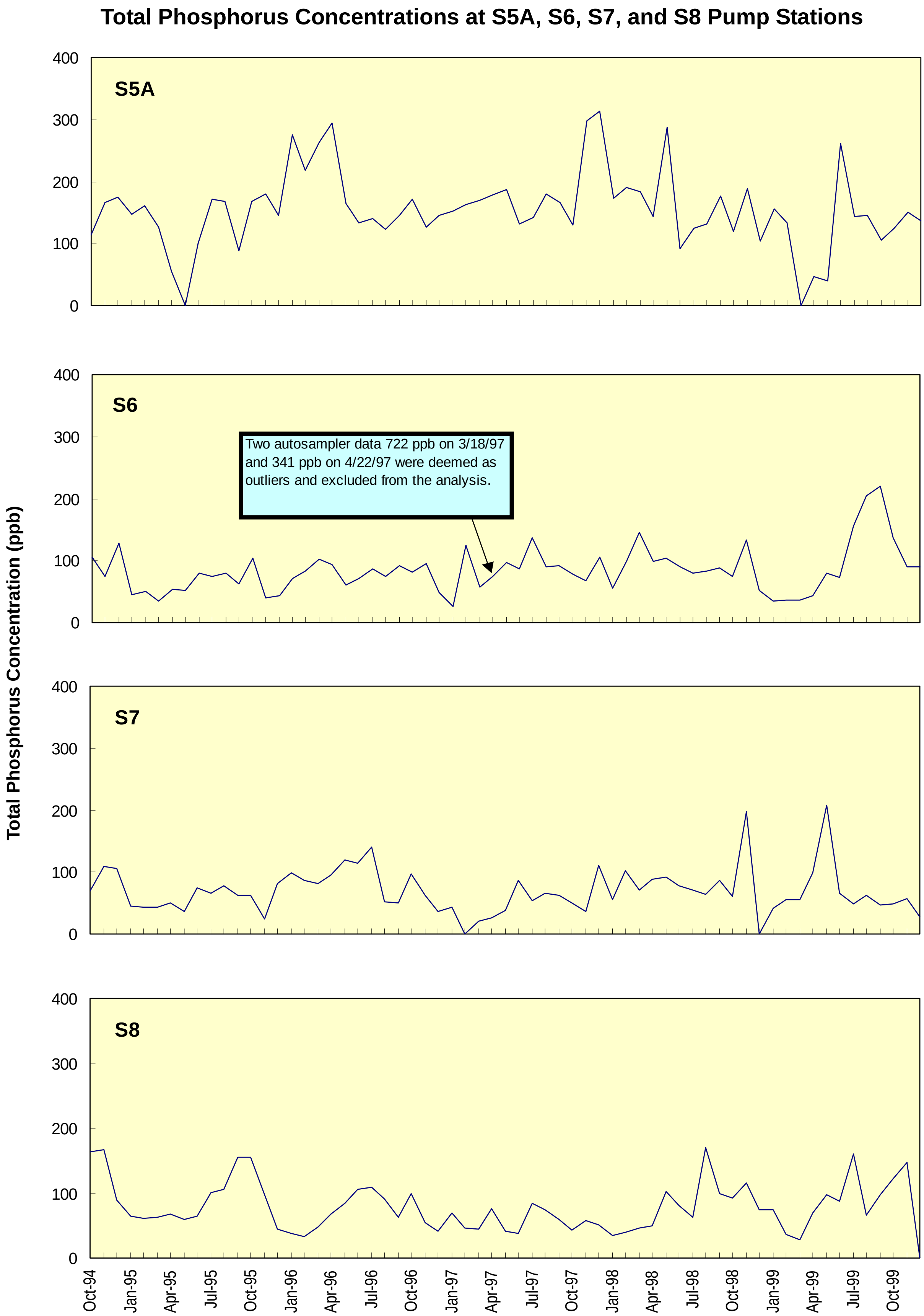
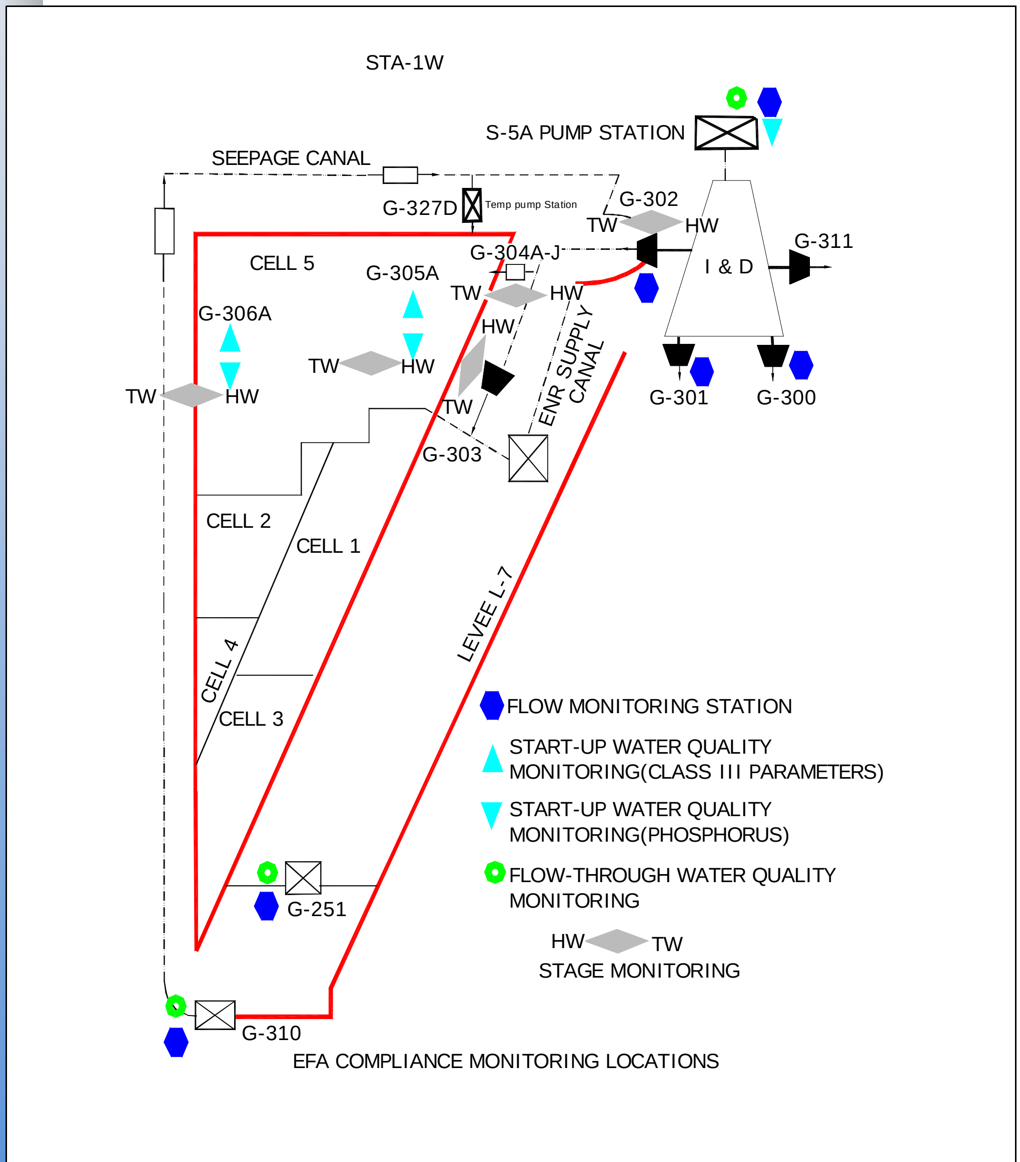


Figure 11. Monthly flow-weighted mean total phosphorus concentrations at major EAA pump stations.

STA-1W

The permit for STA-1W was issued on May 11, 1999. STA-1W passed start-up criteria during the week of Jan. 17, 2000. STA-1W was able to start flow through operations on Feb. 3, 2000 after FDEP received a letter from the District stating that it had met all start-up compliance criteria. Total phosphorus (TP) load reductions were 98, 96 and 95 percent for October, November and December, respectively. The fourth quarter flow-weighted mean TP outflow concentration was about seven times lower than the inflow.



Cell 5 Start-Up Phase

Stormwater Treatment Area-1 West (STA-1W), encompasses the four treatment cells of the Everglades Nutrient Removal Project (ENR) plus newly constructed treatment Cell 5 creating a total effective treatment area of 6,870 acres. The permit for the ENR expired at the end of April 1999. The STA-1W permit went into effect on May 11, 1999. Cell 5 was still in the start-up phase of operation during the fourth quarter of 1999; however, during the week of Jan.17, 2000, Cell 5 passed the start-up criteria for total phosphorus and mercury as set forth in the permit.

In accordance with construction plans, the inflows to STA-1W were diverted July 12, 1999, from pump station G-250 to inflow structure G-302, a component of the new Inflow and Distribution Works for

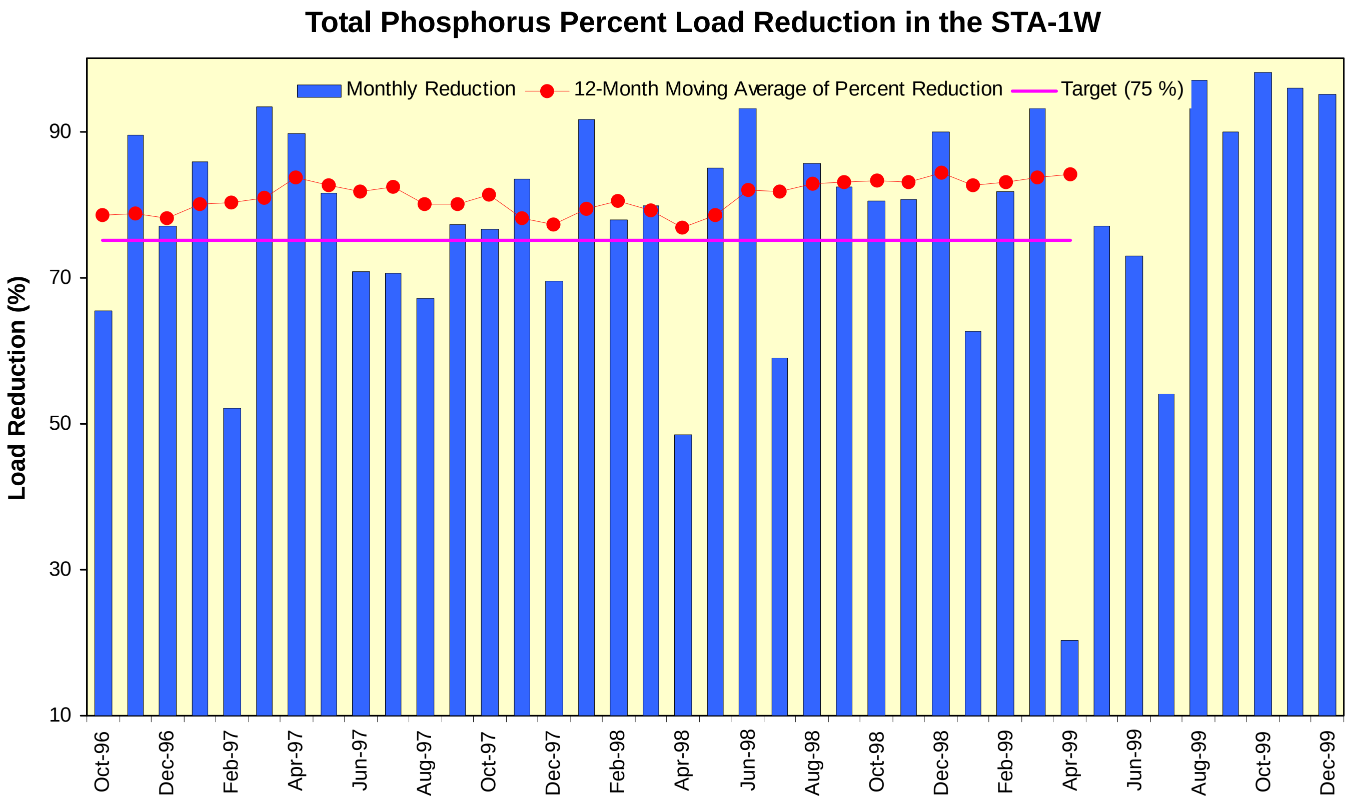


Figure 12. Monthly percent reduction of total phosphorus in the STA-1W Project.

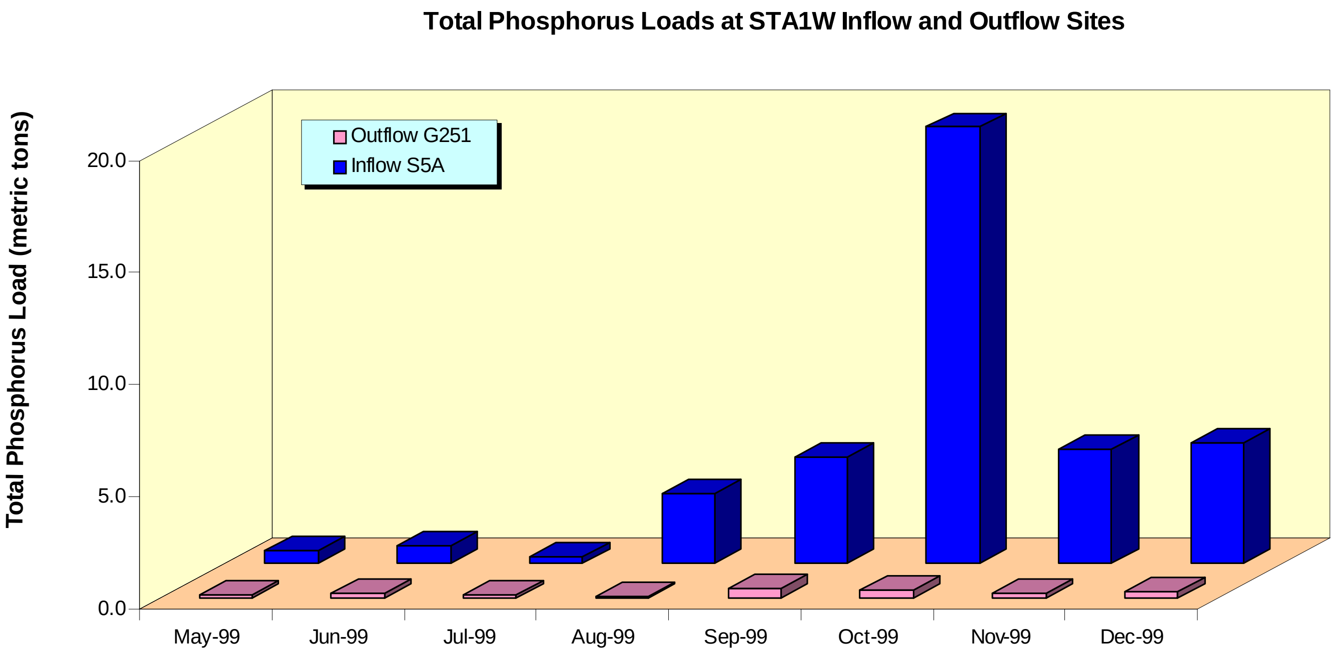


Figure 13. Monthly total phosphorus loads measured at the inflow and outflow sites of the STA-1W.

STAs-1W and 1E. As a result of the diversion, pump station S-5A became the inflow monitoring station for STA-1W. The outflow site (G-251) from the ENR permit remains the same for the STA-1W permit along with the G-310 pump station when it is completed.

Differences Between ENR and STA-1W Permits

The requirement in the ENR permit to achieve a 75 percent reduction in total phosphorus over each 12-month period was not included in the STA-1W permit. In addition, the requirement to compare inflow versus outflow concentrations of total phosphorus using a 28-day residence lag time within the ENR was also not included in the STA-1W permit. As a result of these changes, the 12-month moving total phosphorus reduction values and the 75 percent reduction target were not continued past April 1999 (**Figure 12**). However, the monthly percent load reduction will continue to be included in future reports.

This report presents only the monthly inflow and outflow total phosphorus loads (**Figure 13**) and concentrations (**Figure 14**). A 12-month moving average for the new inflow monitoring station at S-5A can not be calculated until the end of June 2000.

Phosphorus Loads and Concentrations

Total phosphorus loads in STA-1W were reduced by 98 percent in October, 96 percent in November, and 95 percent in December 1999 (**Figure 13**). During the fourth quarter of 1999, 29.9 metric tons of total phosphorus went through S-5A compared with 0.9 metric tons discharged from the outflow of STA-1W (G-251) (**Figure 13**).

The monthly average flow-weighted mean total phosphorus concentrations through S-5A into STA-1W were 127, 149 and 137 part per billion (ppb) for October, November and December, respectively (**Figure 14**). The flow-weighted mean concentrations in the outflows (G-251) were 17, 17, and 19 ppb for the same three months.

Mercury Concentrations

The first quartly sampling at STA-1W for ultratrace mercury occurred on Feb. 16, 2000 in accordance with the STA-1W permit issuance date. The results of this sampling event will be presented in the July 2000 issue of this report.

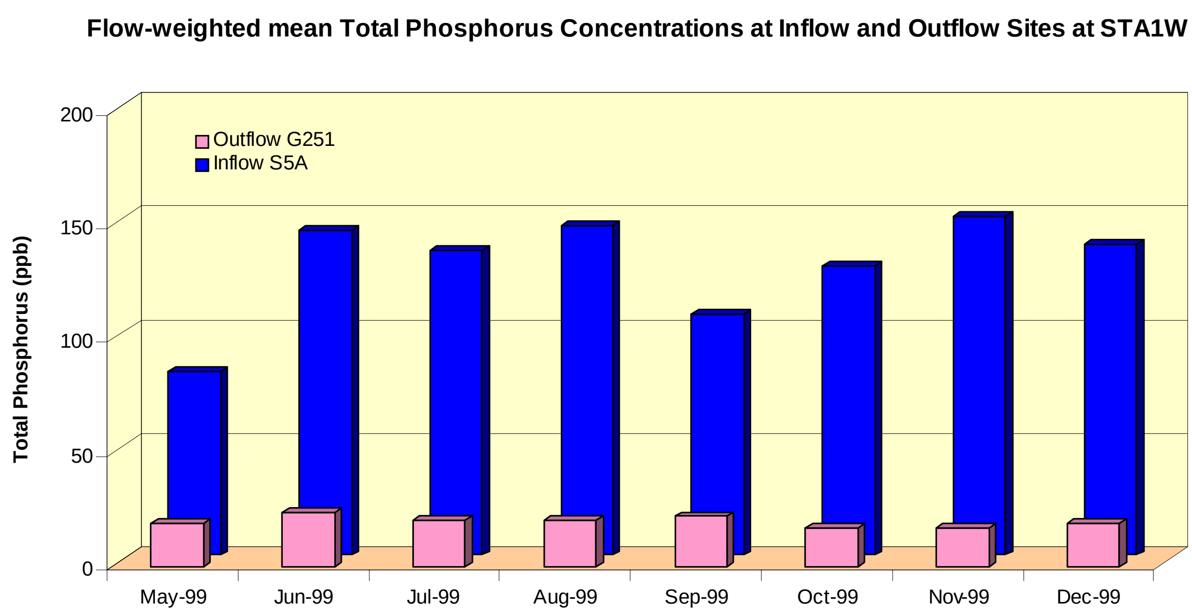
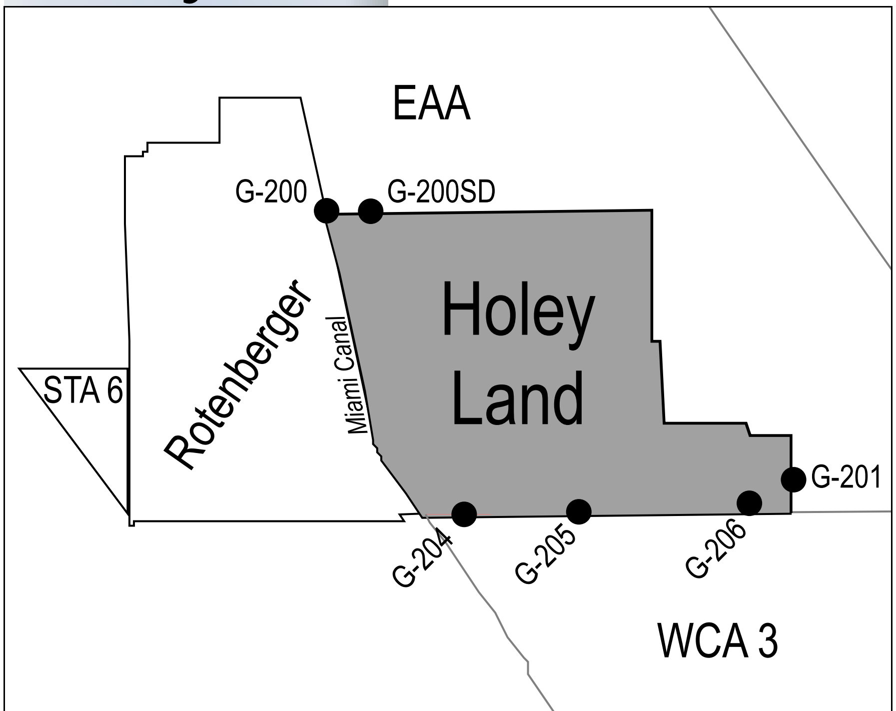


Figure 14. Monthly flow-weighted mean total phosphorus concentrations at the STA-1W Project.

Holey Land



Approximately 3.3 metric tons of phosphorus entered the Holey Land through G-200 during 1999. Thirteen inches of rainfall associated with Hurricane Irene resulted in increased water levels within the management area during the fourth quarter of 1999.

Background

The Holey Land Management Area (Holey Land) is a 35,000-acre tract of land that is operated as a wildlife management area by the Florida Fish and Wildlife Conservation Commission (FFWCC). A Memorandum of Agreement between the Florida Department of Environmental Protection (FDEP), the Board of Trustees of the Internal Improvement Trust Fund, the FFWCC and the South Florida Water Management District established an environmental restoration plan for the Holey Land. As part of the restoration plan, water quality monitoring was implemented to meet the requirements of FDEP Permit No. 06-500809209.

Water quality monitoring is conducted at six surface water inflow and outflow structures as shown in the map above. Nutrient inputs to the Holey Land can occur through surface water inflows from the Miami Canal (G-200) and seepage return pumps (G-200SD and G-201).

Hydrology

The restoration effort also includes an operational plan for maintaining surface water levels (schedule) within the Holey Land. During the wet season from May 15 through Oct. 31, the schedule rises linearly from approximately 10.5 feet National Geodetic Vertical Datum (NGVD) to 12 feet NGVD. During the dry season from Nov. 1 through May 14, the schedule declines linearly from 12 feet NGVD to 10.5 feet NGVD. Prior to 1996, the schedule was maintained between 11.5 feet and 13.5 feet NGVD. During wet years when sufficient rainfall can maintain the stage in the Holey Land according to schedule, less surface water inflow from the Miami Canal is required. The restoration plan requires the outflow structures (G-204, G-205 and G-206) to be closed. However, unregulated flows from the outflow structures occur through seepage.

Figure 15 demonstrates the relationship between rainfall and average stage level in the Holey Land, and inflows from the Miami Canal (G-200) for the period from October 1994 through December 1999. Also shown in **Figure 15** are monthly flows into the management area. Average stage levels increased in the Holey Land during the fourth quarter of 1999. This increase in water levels is attributed to 13 inches of rain associated with October's Hurricane Irene.

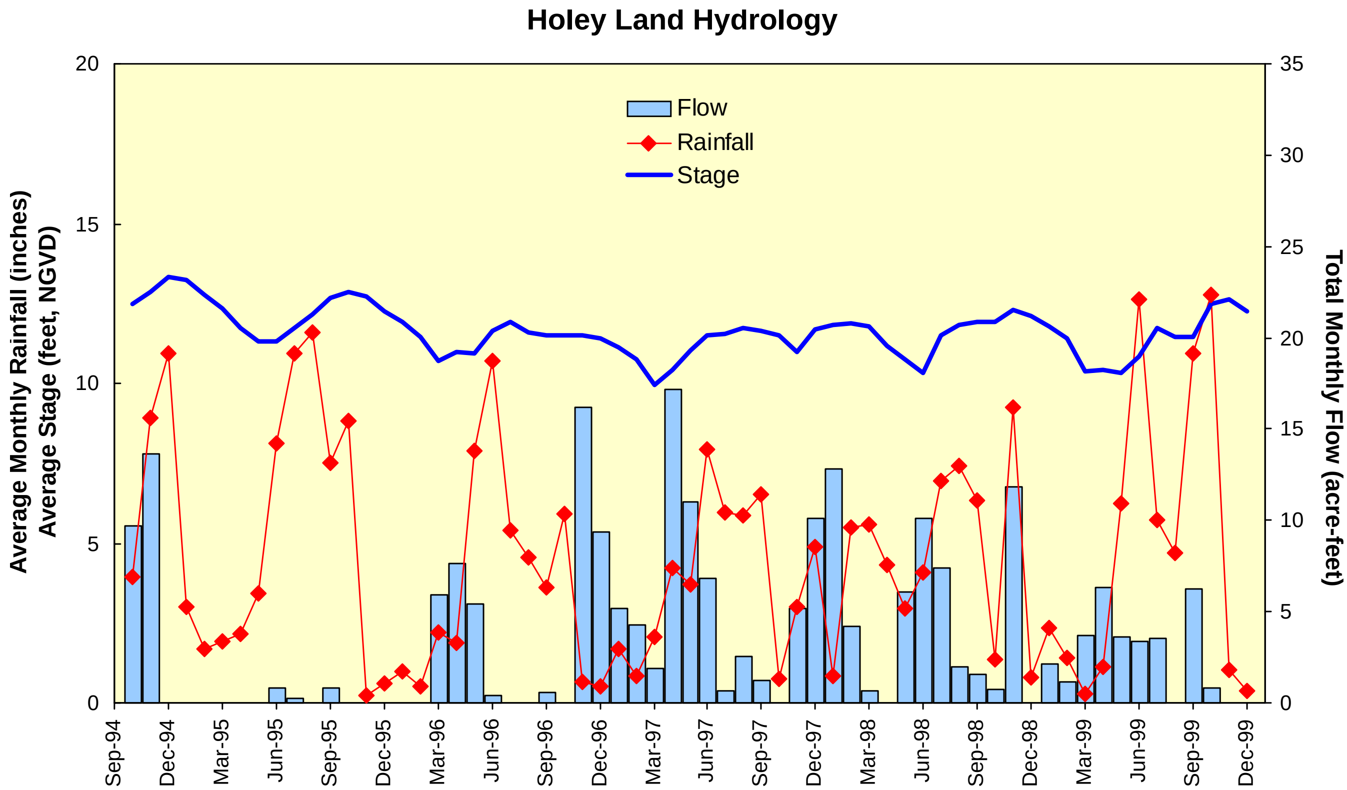


Figure 15. Flow, rainfall and stage measured at inflow station G-200. (Rainfall data are average monthly rainfall in inches.)

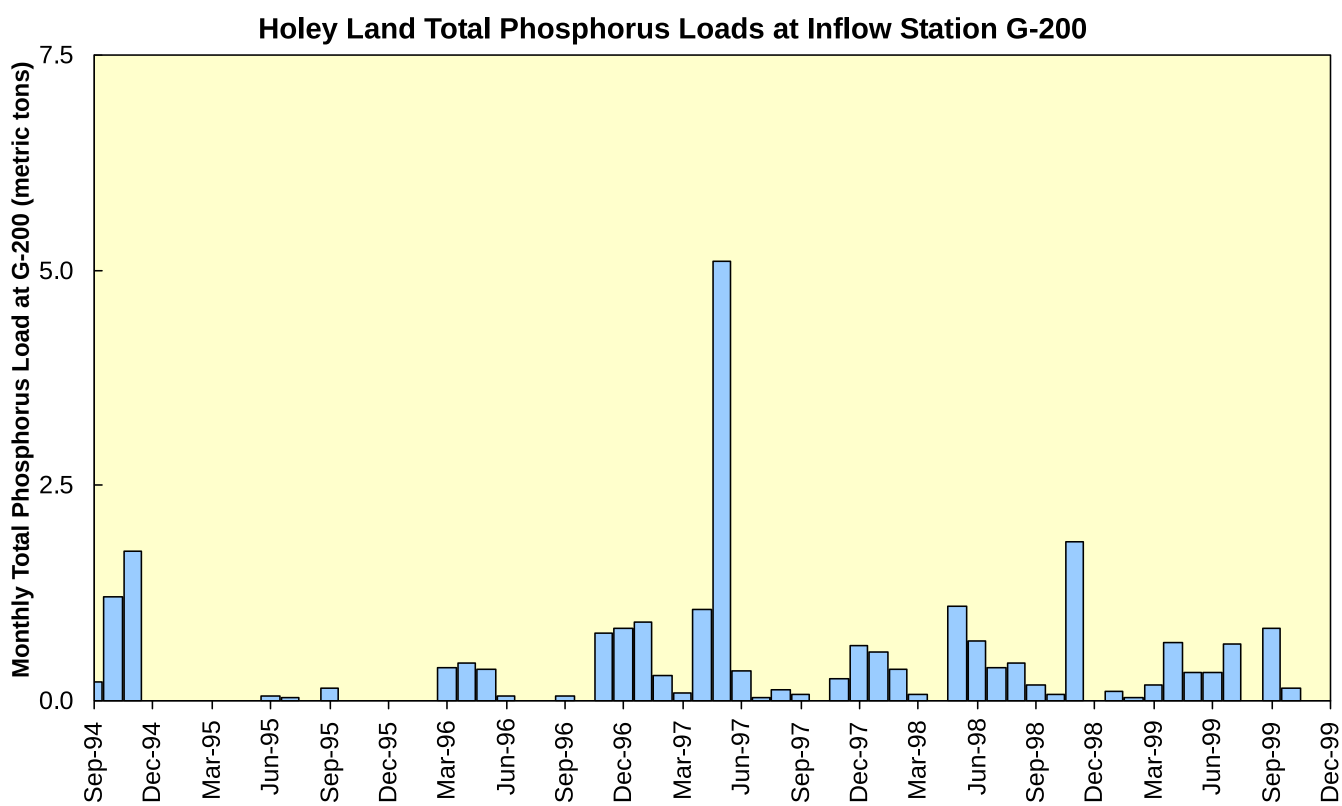


Figure 16. Monthly phosphorus loads discharged into the Holey Land.

Phosphorus Loads

Monthly phosphorus loads calculated for inflow site G200 are presented in **Figure 16**. During the period from October 1994 through December 1999, the monthly load averaged approximately 0.4 metric tons. The highest phosphorus load for this period was observed in May 1997; however, the highest flow during this period occurred in April 1997 (**Figures 16** and **17**). Inflows and loads from G-200 to the Holey Land were at their lowest during 1995 and at their highest during 1997.

During 1999, approximately 3.3 metric tons of phosphorus were discharged from G-200 to the Holey Land (**Figure 16**). Of this total load, only 4 percent was released into the Holey Land during the fourth quarter of 1999. In contrast, an estimated 5.7 metric tons of phosphorus were released from G-200 in 1998. The lower phosphorus load calculated for 1999 reflects a lower discharge of fresh water (approximately 50 percent lower) from G-200 into the Holey Land compared with the same period in 1998.

Phosphorus Concentrations

Figure 17 displays total phosphorus concentrations collected from December 1994 through December 1999 by grab and composite sampling at inflow station G-200. Grab samples have been collected at G-200 since July 1989, while composite samples have been collected at this site since March 1996.

Figure 18 displays total phosphorus data collected quarterly by grab sampling at outflow stations G-204, G-205 and G-206 in the Holey Land from the third quarter of 1994 through the third quarter of 1999.

The total phosphorus concentration for grab samples collected at G-200 during the reporting period averaged 54 parts per billion (ppb). Composite samples have exhibited an average total phosphorus concentration of 80 ppb since March 1996. During 1999, total phosphorus at G-200 averaged 60 ppb for grab samples and 79 ppb for composite samples. The phosphorus concentrations reported in 1999 were similar to those reported for the previous year of monitoring.

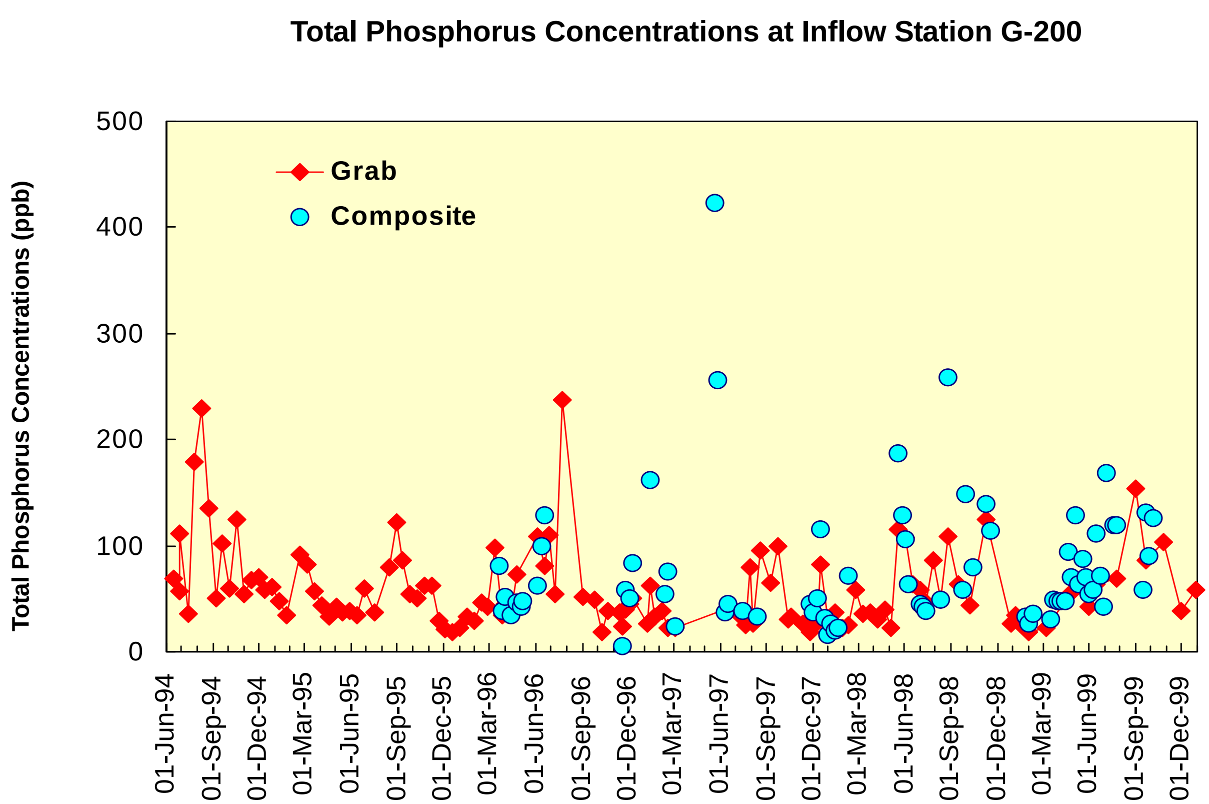


Figure 17. Total phosphorus concentrations for grab and composite samples collected at G200.

A total phosphorus concentration gradient is evident at the three outflow stations. Phosphorus concentrations at G-204 and G-205 are generally higher than at G-206 (**Figure 18**). Historically, total phosphorus concentrations at G-204 and G-205 averaged approximately 50 ppb compared to 26 ppb at G206. The lower total phosphorus concentrations reported for G206 might result from dilution with water from the adjacent seepage canal water that has a phosphorus content lower than in the management area. The canal water is pumped into the Holey Land from seepage return pump stations G-200SD and G-201. Total phosphorus concentrations measured at G-201 and G-200SD averaged 10 ppb and 14 ppb, respectively.

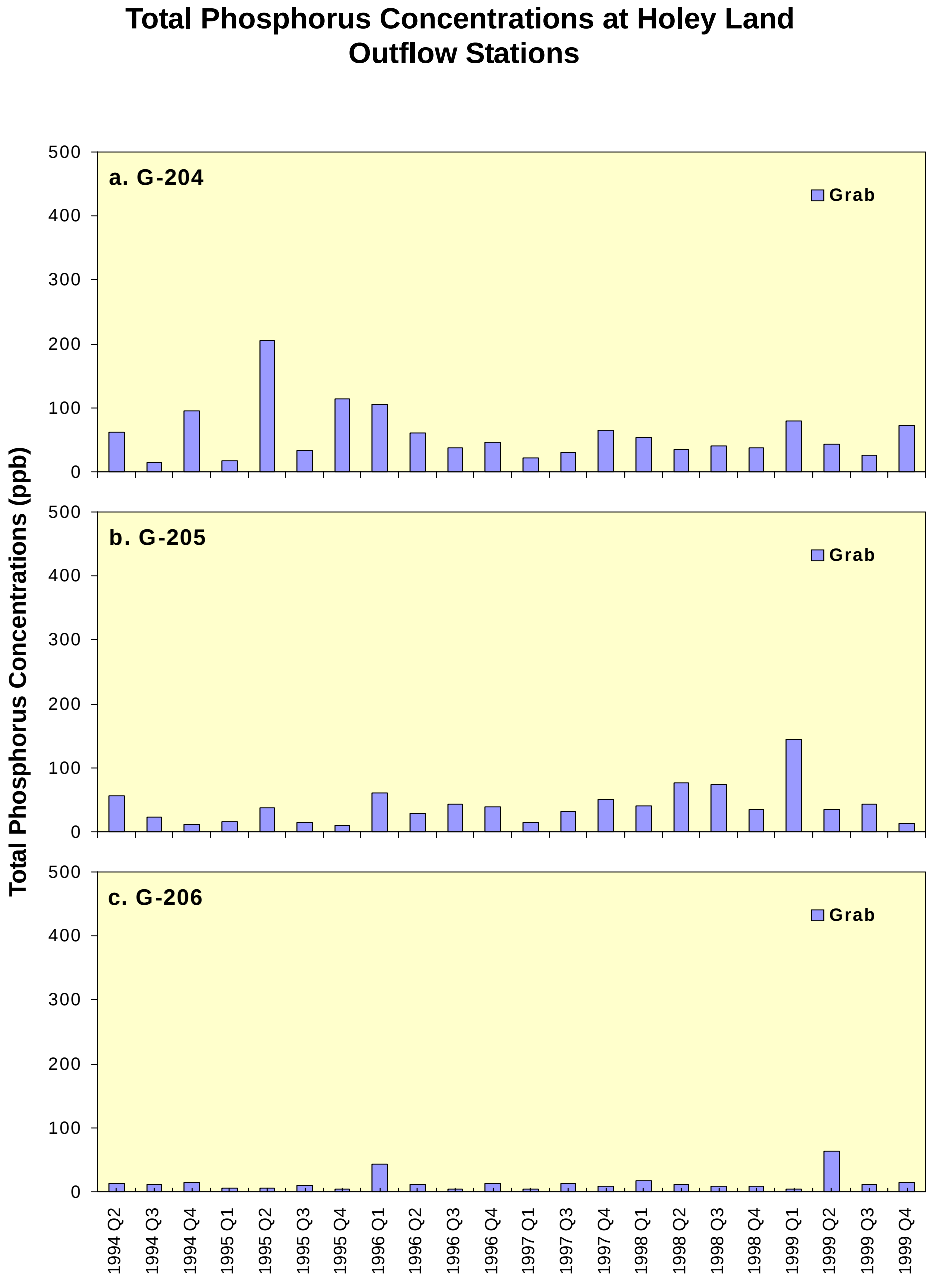
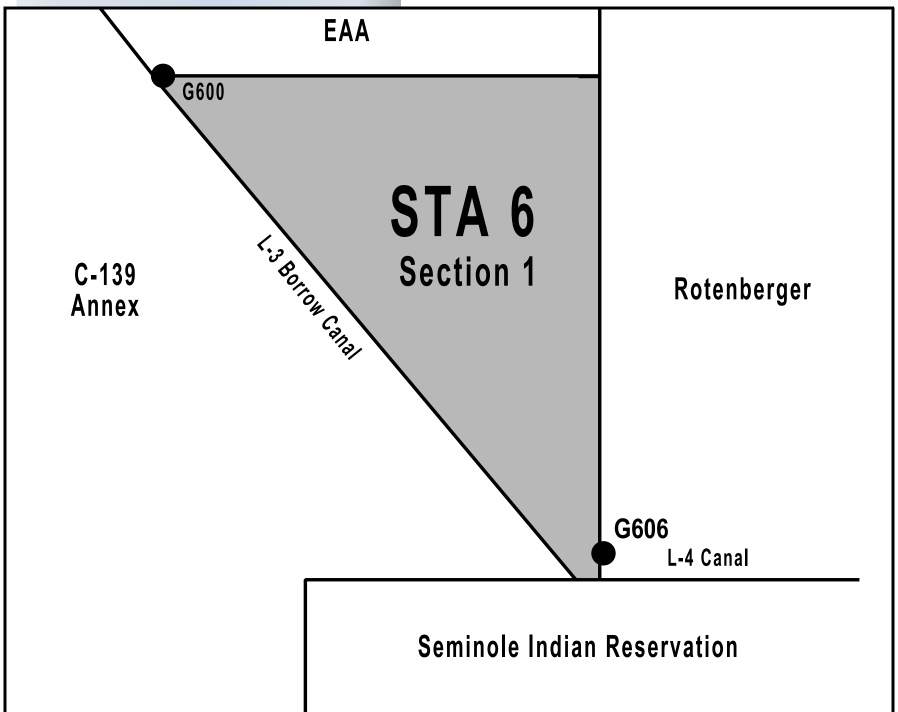


Figure 18. Quarterly total phosphorus concentrations measured for grab samples collected at outflow stations **a.** G-204, **b.** G-205 and **c.** G-206.

STA-6



The total phosphorus load reduction for STA-6 was 86 percent for the fourth quarter of 1999. Concentrations measured at the inflow and outflow averaged 70 ppb and 12 ppb respectively. Total mercury concentrations at the inflow and outflow were 2.0 and 1.4 ng/L, respectively. Methylated mercury concentrations were the same (0.15 ng/L) at the inflow and outflow.

Background

Stormwater Treatment Area 6 (STA-6), Section 1, began full operation on Dec. 9, 1997. It occupies an existing detention area associated with United States Sugar Corporation's (USSC) Southern Division Ranch, Unit 2 development, except for one acre that is within the adjacent Rotenberger Tract. STA6 provides a total effective treatment area of approximately 870 acres. The source of water for STA-6 comes solely from USSC's Unit 2 pump station G-600.

Phosphorus Concentrations

For the fourth quarter of 1999, the total phosphorus concentrations at the inflow and outflow averaged 70 ppb and 12 ppb, respectively. The average total phosphorus concentration for the period of record at the outflow is 22 ppb, or 2 1/2 times lower then the average inflow concentration (**Figure 19**).

Phosphorus Loads

During October 1999, the calculated total phosphorus load at the inflow was considerably higher than normal with 2.22 metric tons as a result of heavy rainfall from Hurricane Irene (**Figure 20**). In November, the load decreased 0.41 metric tons and 0.11 metric tons in December. The calculated outflow loads were 0.31 metric tons in October, 0.07 metric tons in November and 0.02 metric tons in December (**Figure 20**). The total phosphorus load reduction for the fourth quarter of 1999 was 86 percent. The overall total phosphorus load has been reduced by 77 percent since the project began in December 1997.

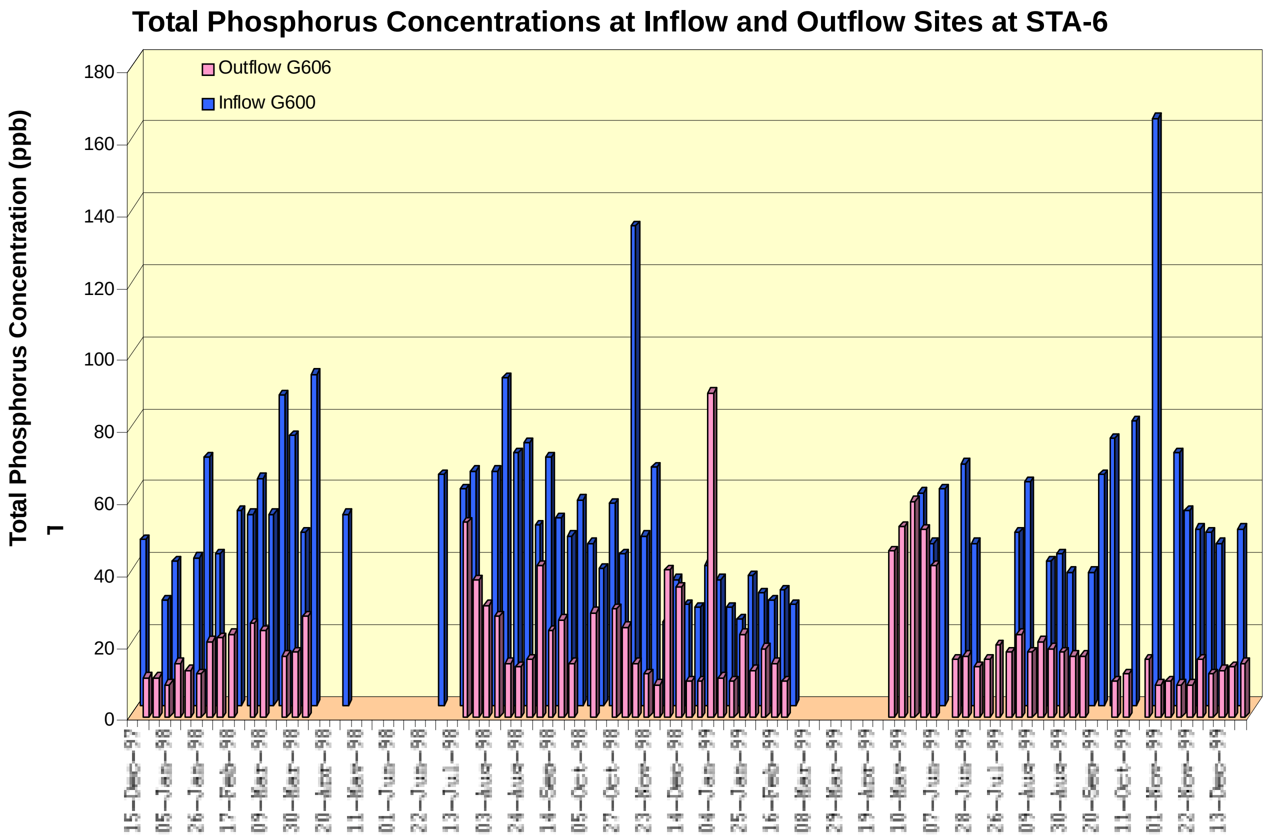


Figure 19. Comparison of the weekly autosampler composite total phosphorus concentrations from the inflow and outflow sites within STA-6, Section 1.

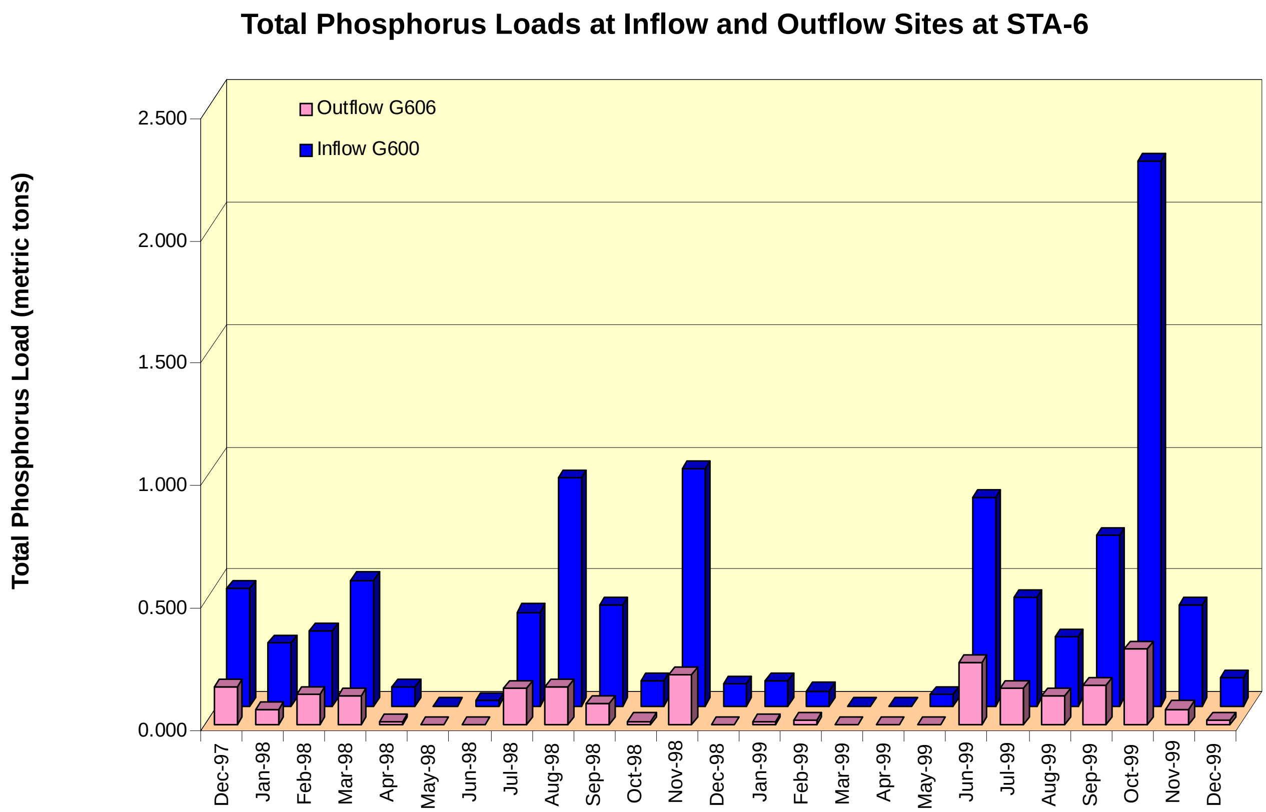


Figure 20. Comparison of the monthly total phosphorus loads from the inflow and outflow sites within STA 6, Section 1.

Mercury Concentrations

The STA-6, Section 1, permit requires the District to collect unfiltered water samples from inflows and outflows quarterly for analysis of total mercury (THg) and methylmercury (MeHg). Sampling for mercury started the first quarter of 1998. Samples for the fourth quarter of 1999 were collected Dec. 20, 1999. The THg concentrations in the inflow and outflow were 2.0 and 1.4 ng/L, respectively (**Table 6** and **Figure 21**).

The MeHg concentrations were the same, 0.15 ng/L, in the inflow and outflow (**Table 6** and **Figure 22**).

Both the inflow and outflow sites at STA-6 have THg and MeHg concentrations comparable to those historically observed in STA-1W and other areas in the Everglades. Total mercury concentrations measured in the inflows and outflows were below the Class III Water Quality Standard of 12 nanograms per liter (ng/L).

Table 6. Concentrations of Total Mercury and Methylmercury in STA-6 surface waters (units, ng/L)

Year	Quarter	Total Mercury Concentration				Methylmercury Concentration			
		Inflow	remark[1]	Outflow	remark[1]	Inflow	remark[1]	Outflow	remark[1]
1998	1	0.89		1.12		-0.127	J4	-0.289	J4
1998	2	1.30	I	0.81	I	-0.038	J4U	-0.038	J4U
1998	3	-1.45	?	-1.47	?	-0.300	J A	-0.218	J
1998	4	1.18		1.51	A	0.270		0.230	A
1999	1	-1.61	J3A	-0.67	J3I	0.207		0.076	I
1999	2	1.32		0.59		0.053	IA	0.038	I
1999	3	1.50	A	1.00		0.310		0.071	A
1999	4	2.00		1.40		0.150		0.150	A

[1]U = Indicates that the compound was analyzed for but not detected; A= mean of two or more lab analyses, I = The reported value is between the MDL and PQL. J = Estimated value; value not accurate. J3 = The reported value failed to meet the established quality control criteria for either precisions or accuracy. ? = Data is rejected and should not be used; some or all of the quality control data for the analyte were outside criteria, and the presence or absence of the analyte can not be determined from the data. J4 = The sample matrix interfered with the ability to make an accurate determination.

Negative values = Data did not meet quality control check; for qualifier definitions, see rule FDEP rule 62-160.

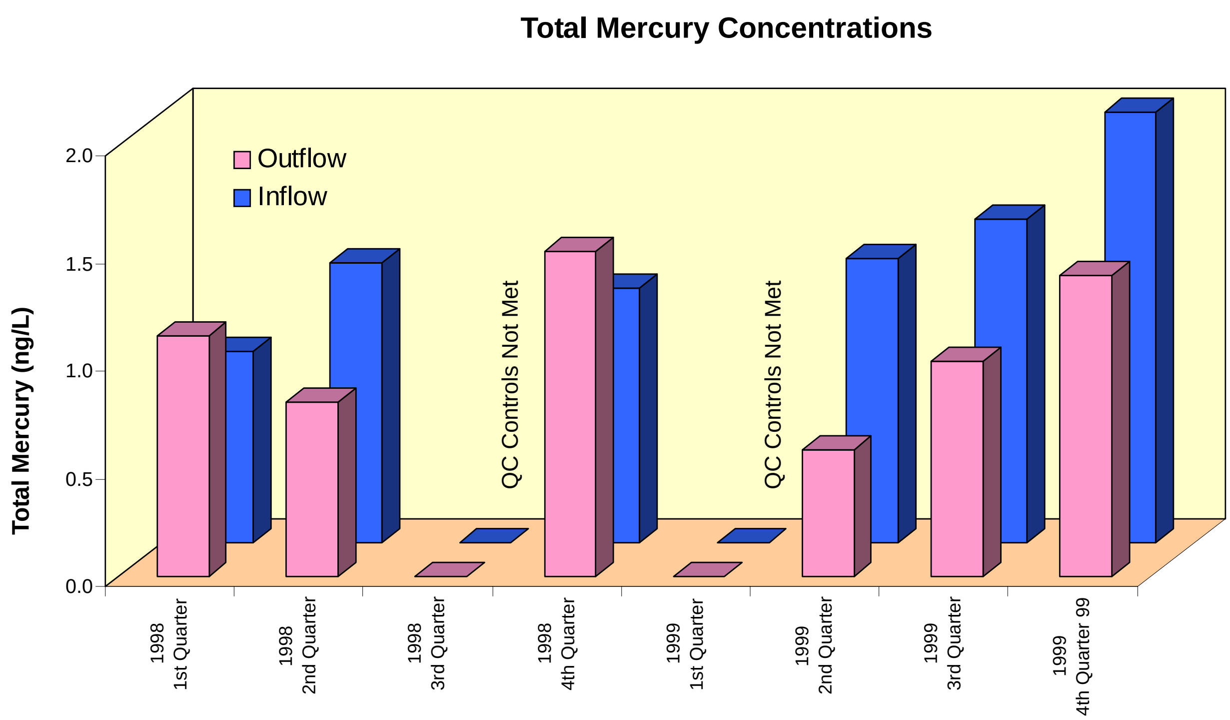


Figure 21. Surface water total mercury concentrations at STA-6. Samples are collected quarterly.

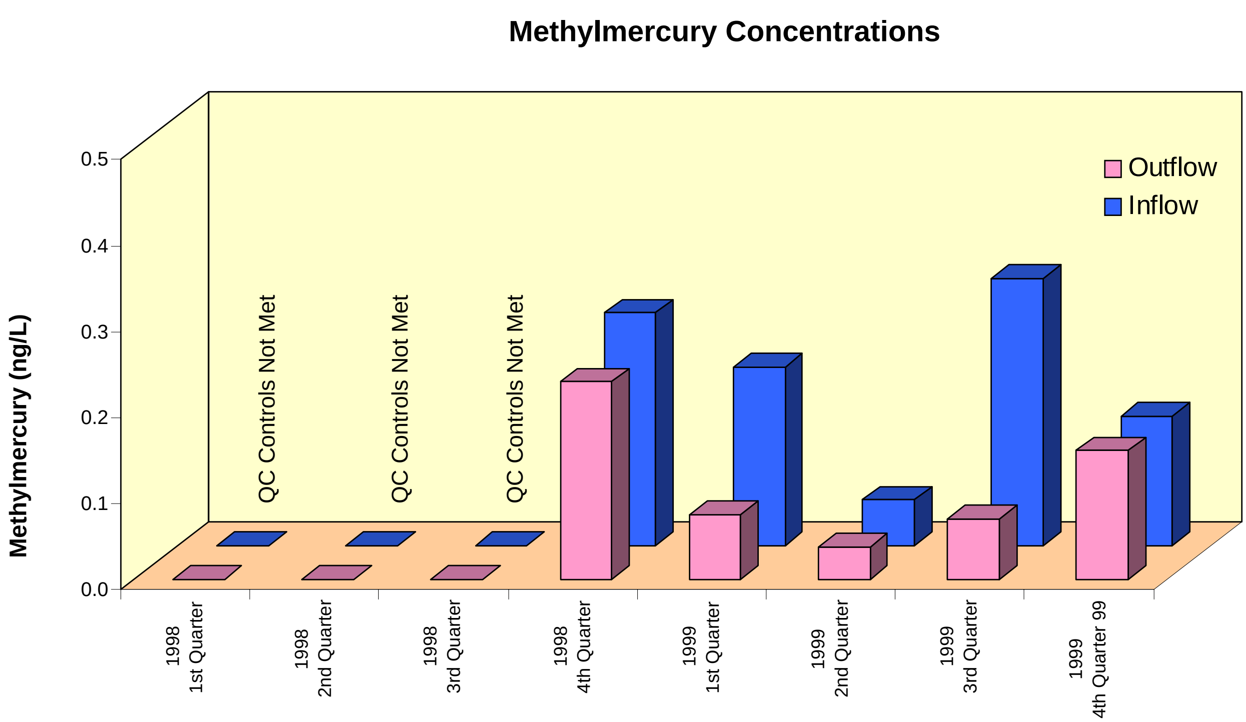
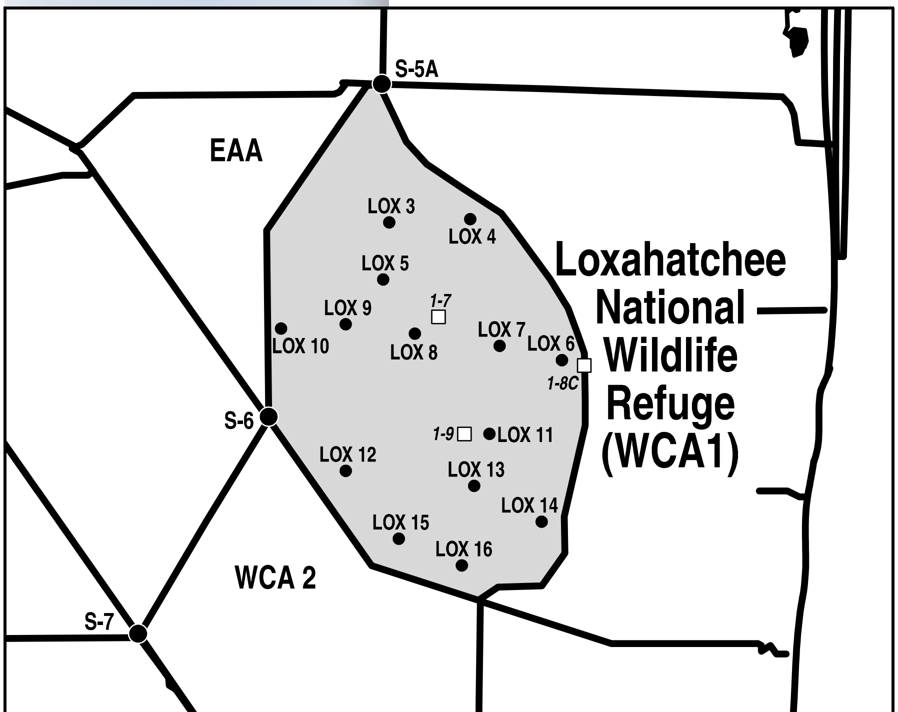


Figure 22. Surface water methylmercury concentrations at STA-6. Samples are collected quarterly.

Loxahatchee National Wildlife Refuge



The geometric mean of total phosphorus concentrations in October and November 1999 both exceeded the interim and long-term limits. The December geometric mean concentration was equal to the interim limit, but greater than the long-term limit. This is the third and fourth time the interim limit has been exceeded since the Feb. 1, 1999, compliance date.

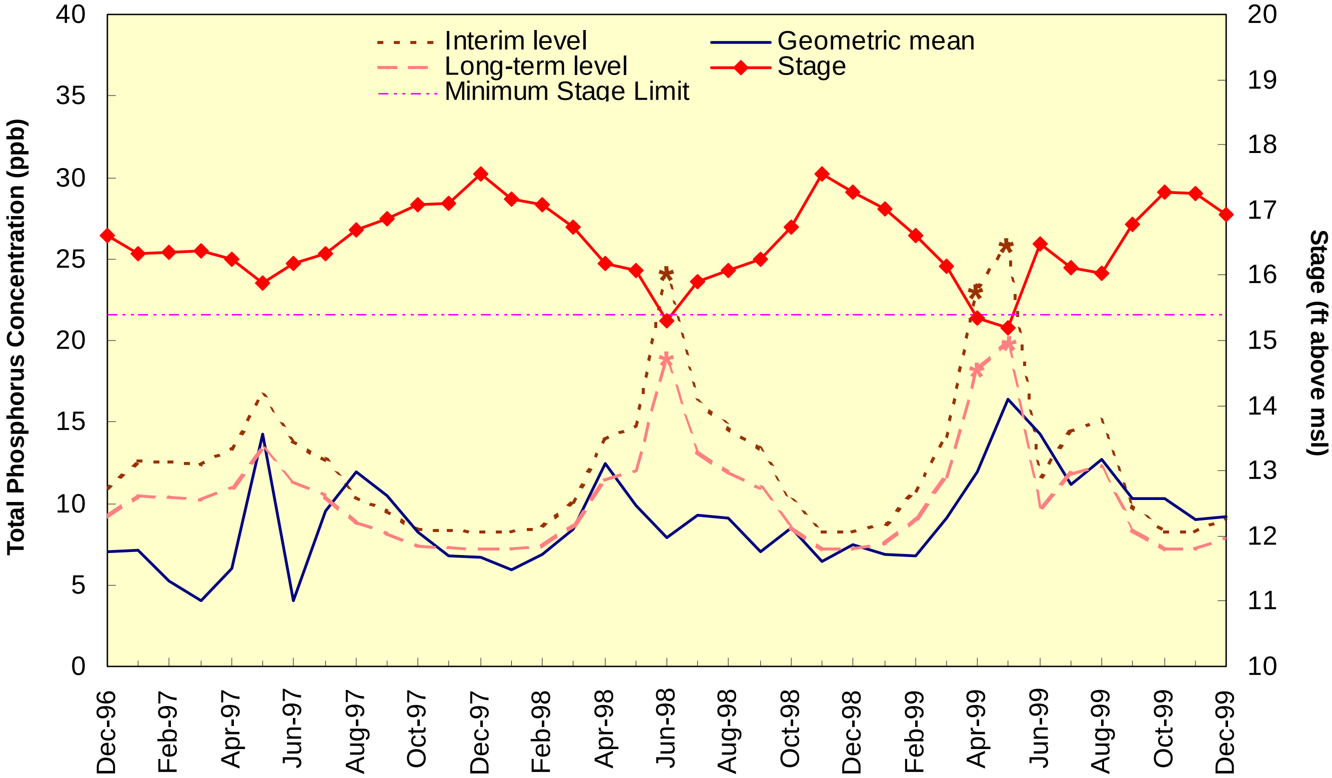
Phosphorus Concentrations

The Settlement Agreement entered into by the federal government, the State of Florida and the South Florida Water Management District in 1991 to end the Everglades lawsuit stipulates interim and long-term phosphorus concentration levels for the Loxahatchee National Wildlife Refuge (Refuge). The interim and long-term concentration levels must be met by Feb. 1, 1999, and Dec. 31, 2006, respectively. Interim and long-term concentration levels vary monthly because they are calculated as a function of water level measured at gaging stations 1-7, 1-8C and 1-9 within the Refuge. Total phosphorus concentrations are determined from water samples collected at the 14 interior marsh stations (LOX 3 through LOX 16, see the map above) and compared with the Settlement specified levels.

The geometric means calculated from total phosphorus concentrations measured in water samples collected in October, November and December 1999 were 10.3, 9.0 and 9.1 parts per billion (ppb), respectively. These geometric mean concentrations were greater than the calculated interim and long-term limits for October and November (**Figure 23**). The interim and long-term limits for both October and November were 8.3 and 7.2 ppb, respectively, while the interim and long-term limits for December were 9.1 and 7.9 ppb, respectively. The October and November results were the third and fourth time within 12 consecutive sample collections that the interim limit was exceeded. Average stages in the Refuge were 17.28 feet in October, 17.25 feet in November and 16.94 feet in December.

When excursions above the interim concentration level occur, the Settlement Agreement requires the Everglades Technical Oversight Committee to review the data and forward their opinions and recommendations to their respective agencies for relevant action.

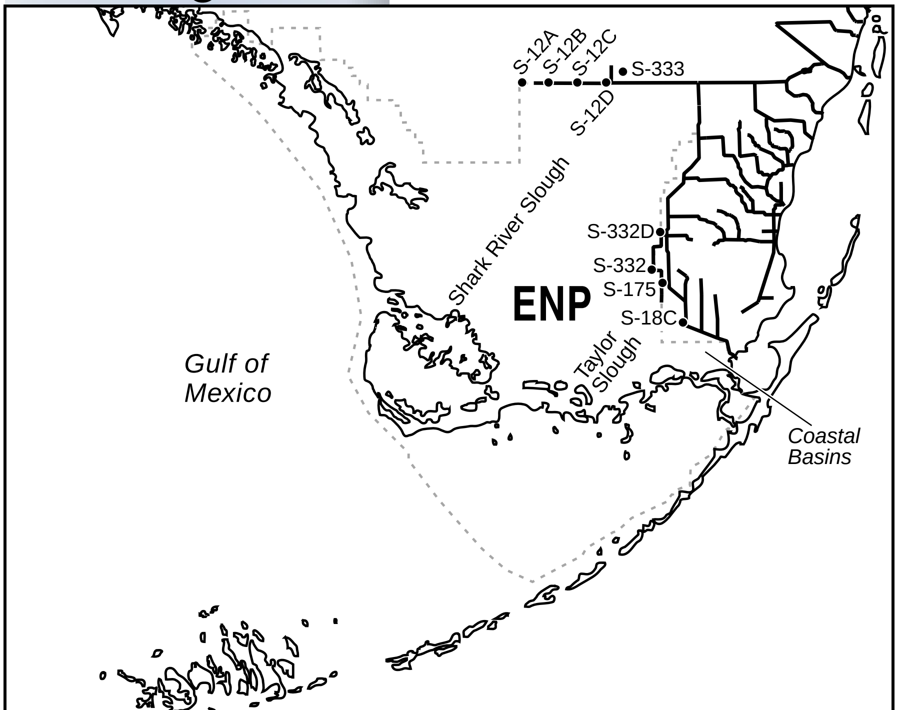
Monthly Total Phosphorus Geometric Mean Concentration Levels for Loxahatchee National Wildlife Refuge



* Denotes limits were not applicable because the average stage was lower than 15.4 feet.

Figure 23. Monthly total phosphorus geometric mean concentration levels for the Loxahatchee National Wildlife Refuge compared to the interim and long-term targets. The observed concentrations targets are adjusted for fluctuations of water level.

Everglades National Park



The Shark River Slough 12-month moving flow-weighted mean total phosphorus concentrations for October through December 1999 were less than the interim concentration limits, but greater than the long-term limits . Taylor Slough and the Coastal Basins 12-month moving flow-weighted mean total phosphorus concentrations for the same period were consistently less than the 11 ppb limit. Grab samples for total phosphorus taken by the U.S. Army Corps of Engineers just after Hurricane Irene at structures S-332 and S-332D had concentrations of 35 and 56 ppb, respectively.

Shark River Slough

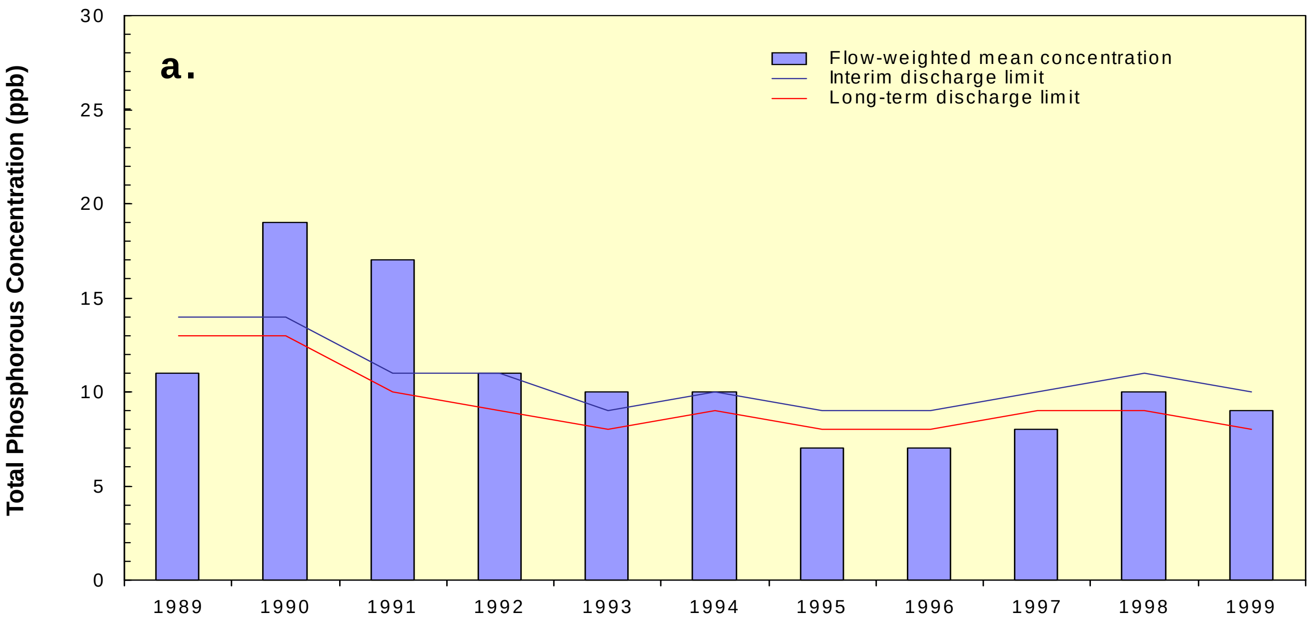
The Settlement Agreement of 1991 set separate interim and long-term total phosphorus concentration limits for Shark River Slough to be met by Oct. 1, 2003, and Dec. 31, 2006, respectively. The limits apply to the water year ending Sept. 30. The long-term total phosphorus concentration limit for inflows to Shark River Slough through structures S-12A, S-12B, S-12C, S-12D and S-333 represents the concentrations delivered during the Outstanding Florida Waters baseline period of Mar.1, 1978, to Mar. 1, 1979, and is adjusted for variations in flow. In addition, the Settlement Agreement requires that phosphorus concentrations be presented as 12-month moving flow-weighted means.

Inflow concentrations of total phosphorus to the Everglades National Park through Shark River Slough are compared to the interim and long-term limits at the end of each water year (**Figure 24a**). The 12-month moving flow-weighted mean total phosphorus concentration ending September 1999 was 9.5 ppb. The interim and long-term limits for September 1999 were 9.8 and 8.2 ppb, respectively.

Figure 24b presents the monthly 12-month moving flow-weighted mean concentrations for the last two years and the composite total phosphorus concentrations for each sampling event. The 12-month flow-weighted mean concentrations for October, November and December 1999 were 9.2, 8.9 and 9.2 ppb, respectively. These values were below the interim discharge limits of 9.4, 10.1 and 9.8 ppb for October, November and December, respectively, but above the long-term limits of 7.7, 7.6 and 7.6 ppb for these same months, respectively.

The Settlement Agreement also stipulates that the percent of composite samples having concentrations greater than 10 ppb total phosphorus in any water year must not exceed a calculated value based on annual flow into Shark River Slough through the inflow structures. For the 12-month periods ending October, November and December 1999, the percent of composite samples with total phosphorus concentrations greater than 10 ppb was 33.3 each month. This percentages was less than the allowable limits of 40.3, 40.1 and 40.1 percent for the respective months.

Discharge Limits for Shark River Slough (S-12A, S-12B, S-12C, S-12D, and S-333)



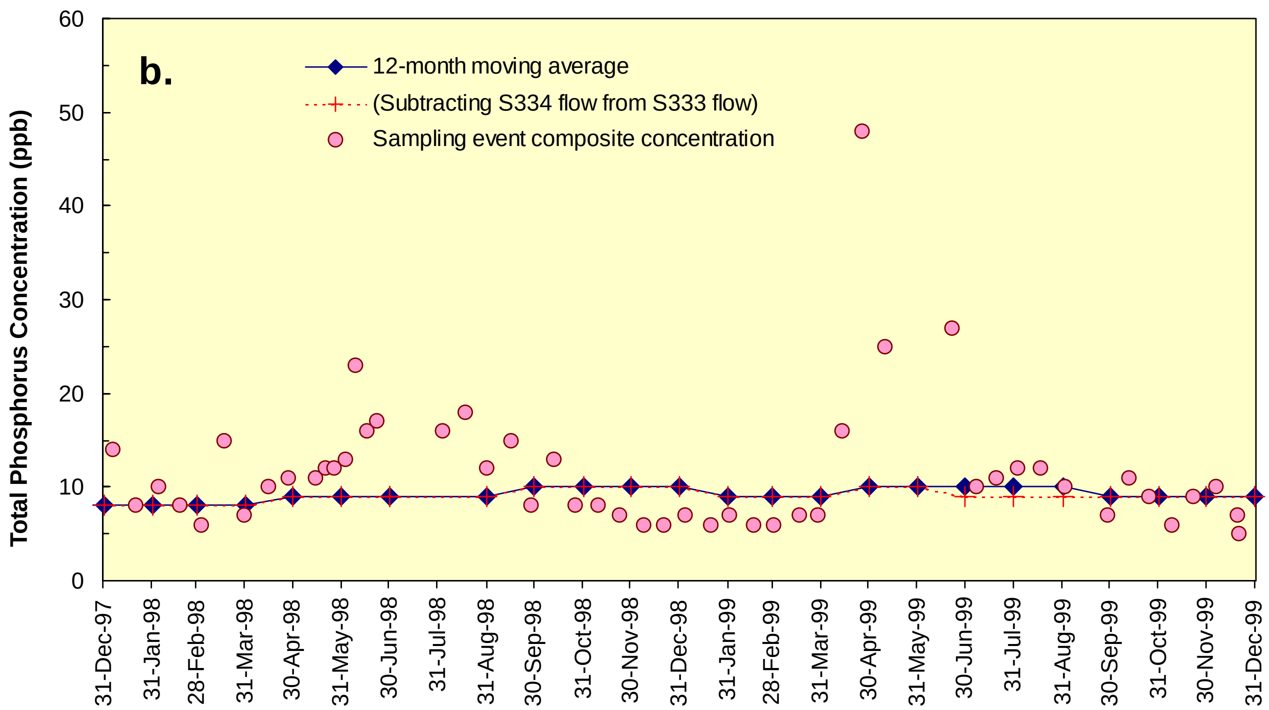


Figure 24. 12-month moving flow-weighted mean total phosphorus concentration in the inflows to Everglades National Park (ENP) through Shark River Slough compared to the interim and long term targets. **a.** Concentrations at the end of each water year. **b.** 12-month moving average concentration at the end of each month and the composite concentration for each sampling event.

Taylor Slough and The Coastal Basins

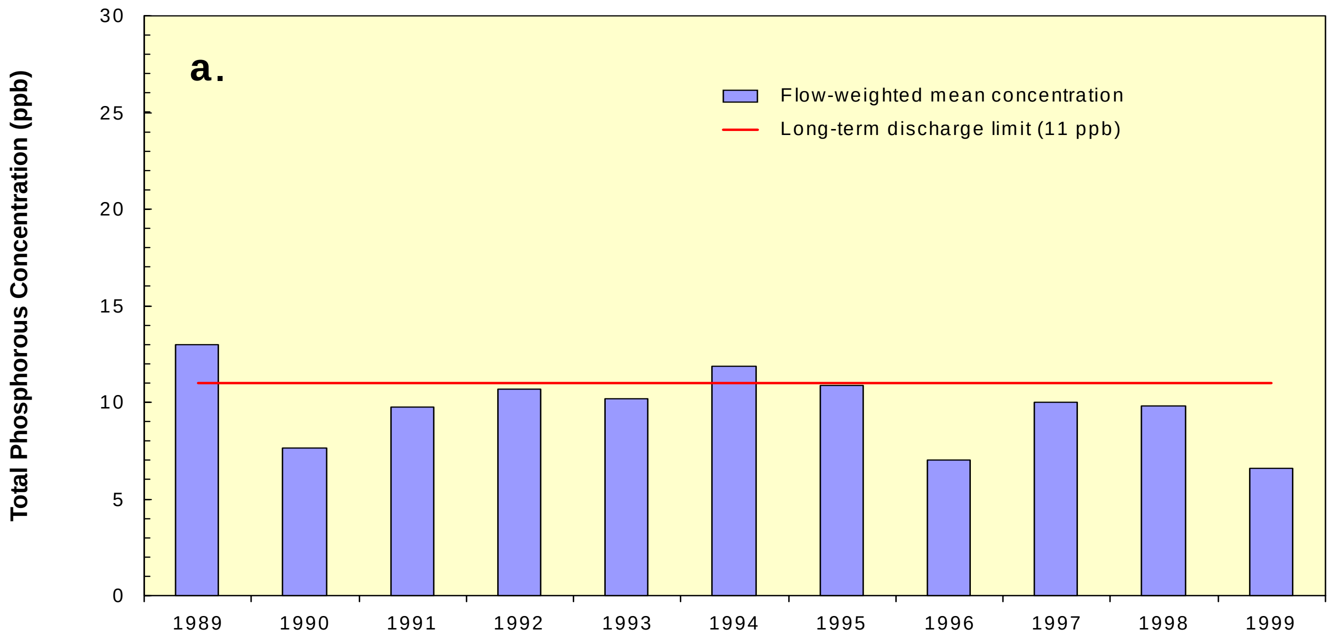
Under the Settlement Agreement, a single limit for total phosphorus of 11 ppb (to be met by Dec. 31, 2006) was set for the two points of inflow to Taylor Slough (S-332 and S-175) and the inflow point to the Coastal Basins (S-18C). The limit applies to the water year ending September 30. Beginning in August 1999, structure S-332D, a new spillway constructed by the U.S. Army Corps of Engineers, began operation. The structure is adjacent to spillway S-174 and pumps water from the L-31N canal into the L-31W canal. Flow and water quality data collected at S-332D were not available for the January 2000 issue of this report.

The 12-month moving flow-weighted mean total phosphorus concentrations for Taylor Slough and the Coastal Basins during August and September 1999 were reported in the January 2000 report as 8.5 and 6.7 ppb, respectively. With the inclusion of the S332D data, the August and September values became 8.3 and 6.3 ppb, respectively, (**Figure 25a**).

Figure 25b presents the monthly 12-month moving flow-weighted mean concentrations for the last two years and the composite total phosphorus concentrations for each sampling event. The 12-month flow-weighted mean concentrations for October, November and December 1999 were less than the 11 ppb limit with concentrations of 7.0, 7.2 and 7.1 ppb, respectively.

The Settlement Agreement stipulates that the percent of composite samples greater than 10 ppb total phosphorus in any water year must not exceed a fixed value of 53.1 percent. The percent of composite samples with concentrations greater than 10 ppb was 9.4, 8.1 and 8.1 for the 12-month periods ending October, November and December, respectively.

Discharge Limits for Taylor Slough (S-332 and S-175) and the Coastal Basins (S-18C)



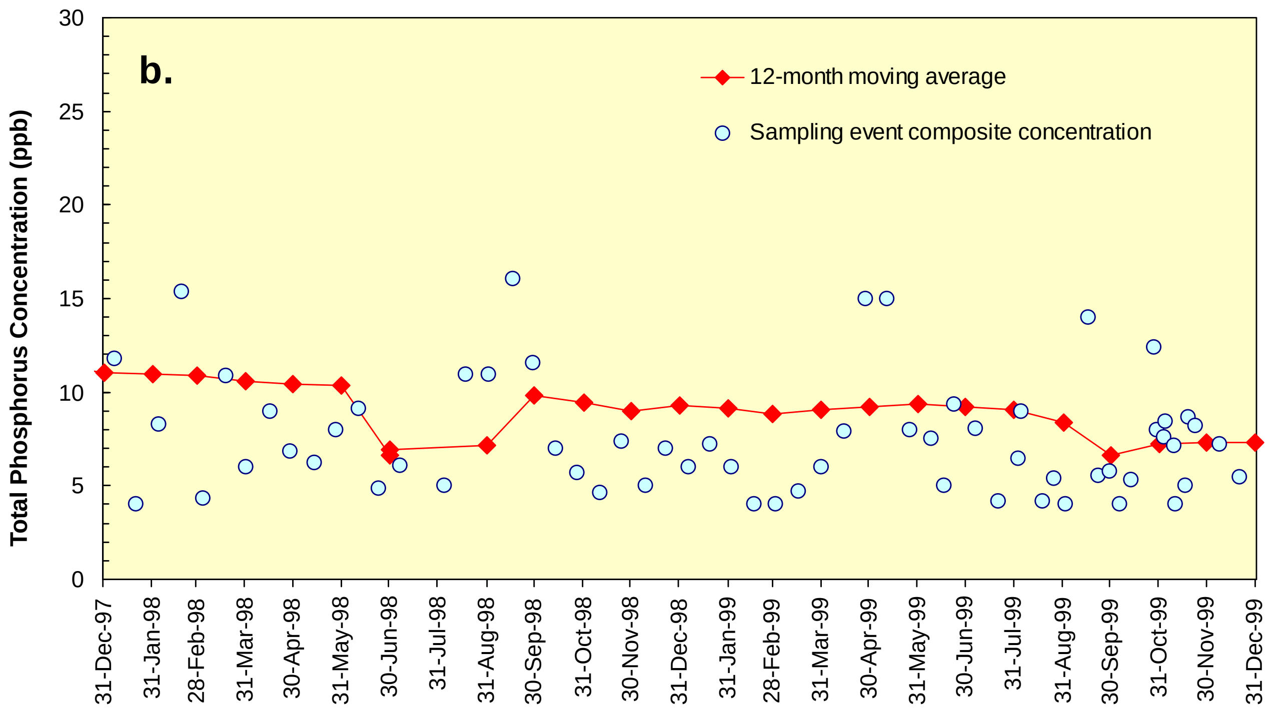


Figure 25. 12-month moving flow-weighted mean total phosphorus concentration in the inflows to Everglades National Park (ENP) through Taylor Slough and the Coastal Basins compared to the long term target. **a.** Concentrations at the end of each water year. **b.** 12-month moving average concentration at the end of each month and the composite concentration for each sampling event.

Effects of Hurricane Irene

Total phosphorus data in **Figure 24b** and **Figure 25b** do not indicate any effects of Hurricane Irene (Oct. 14-16) because of the biweekly nature of the grab sampling program mandated by the Settlement Agreement. Samples were collected on October 12 and 25 at the Shark River Slough structures and October 13 and 27 at the Taylor Slough and Coastal Basins structures. Although no grab samples were collected while Irene was over South Florida, some samples were obtained after the hurricane and close to the dates of peak flows.

Figure 26 and **Figure 27** present the mean daily flows and the total phosphorus grab sample data for each Shark River Slough structure plus S-334. The vertical line in each figure indicates the period that Hurricane Irene passed through Everglades National Park.

Flows through the S-12 structures began increasing rapidly on October 14 and continued increasing until the peak flows were reached at S-12D on November 3 and at S-12A, B and C on November 7 (**Figure 26**). As indicated in **Figure 27**, total phosphorus concentrations measured in samples collected at the S-12 structures on Oct. 25 and Nov. 8 were the same or lower than the pre-hurricane data collected on Oct. 12.

Figure 28 and **Figure 29** present the mean daily flows, total phosphorus grab sample data for each Taylor Slough and Coastal Basins structure. Additional total phosphorus data were collected several days after Hurricane Irene by the U.S. Army Corps of Engineers using grab sampling and seven-day time composite samples at S-175, S-332 and S-332D.

Flows through S-175 and S-18C increased rapidly as Hurricane Irene entered the Park. Flows peaked on October 17 at S-18C and on October 21 at S-175 (**Figure 28**). Flow through S-332 had been high prior to the hurricane, peaked on October 17, and remained high for the remainder of 1999. Prior to the hurricane, flow into the L-31W canal had been through S-174. The pumps at S-332D were started on Oct. 15. The combined flow through these structures peaked on October 16 and then decreased slowly after Irene passed through the area. The bi-weekly total phosphorus grab sample data as well as the data collected by the U.S. Army Corps of Engineers are presented in **Figure 29**.
At S-175 a total phosphorus concentration of 15 ppb was measured from a grab sample on Oct. 21. Grab samples collected at S-332 and S-332D on Oct. 19 had total phosphorus concentrations of 35 and 56 ppb, respectively. No samples were collected at S-18C between Oct. 13 and 27. The seven-day time composite samples collected on Oct. 19 at S-332 and S-332D had total phosphorus concentrations of 51 and 10 ppb, respectively.

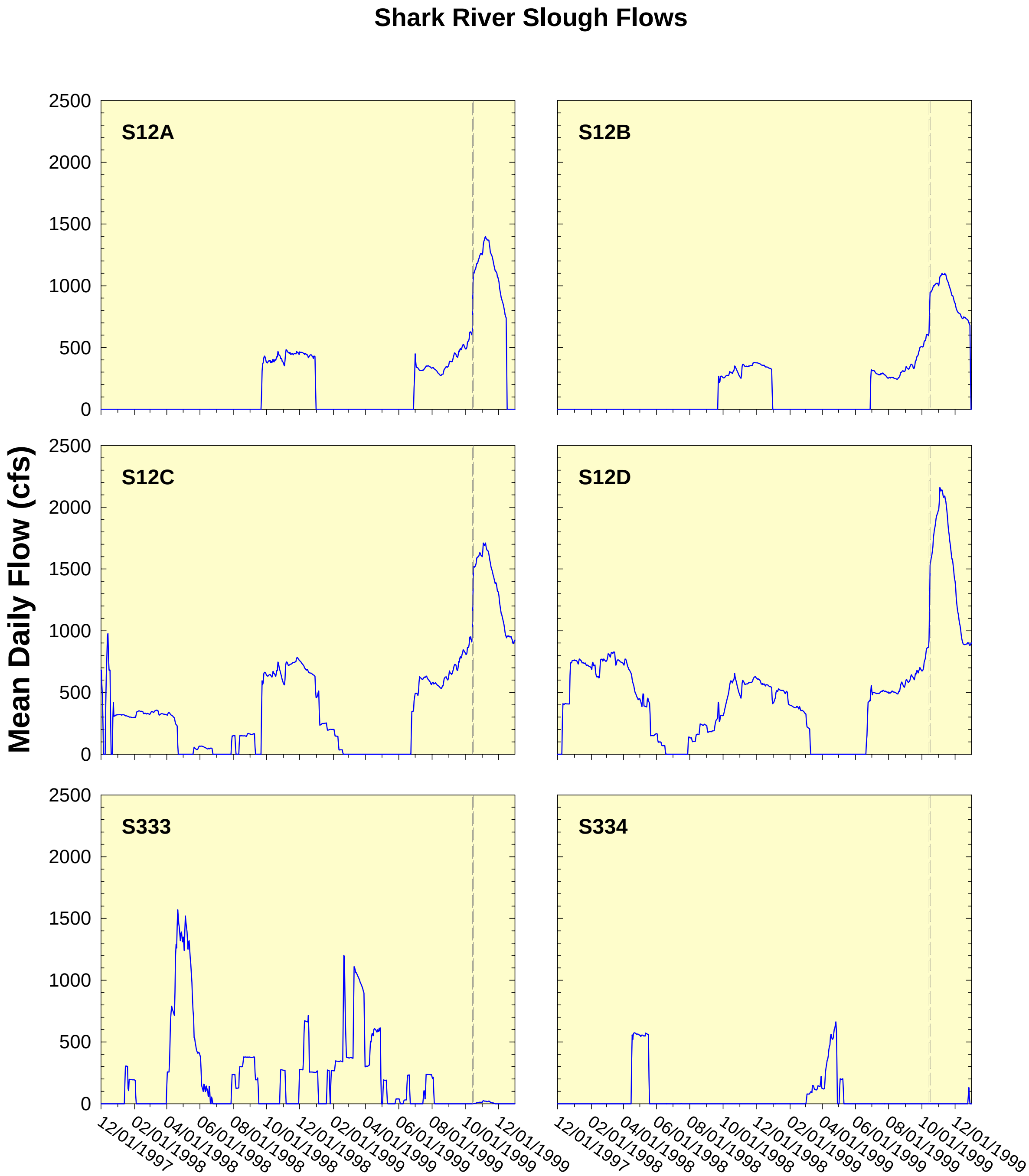


Figure 26. Mean daily flows for the Shark River structures and S-334. Vertical line indicates the period Hurricane Irene passed through the Everglades National Park on October 16, 1999.

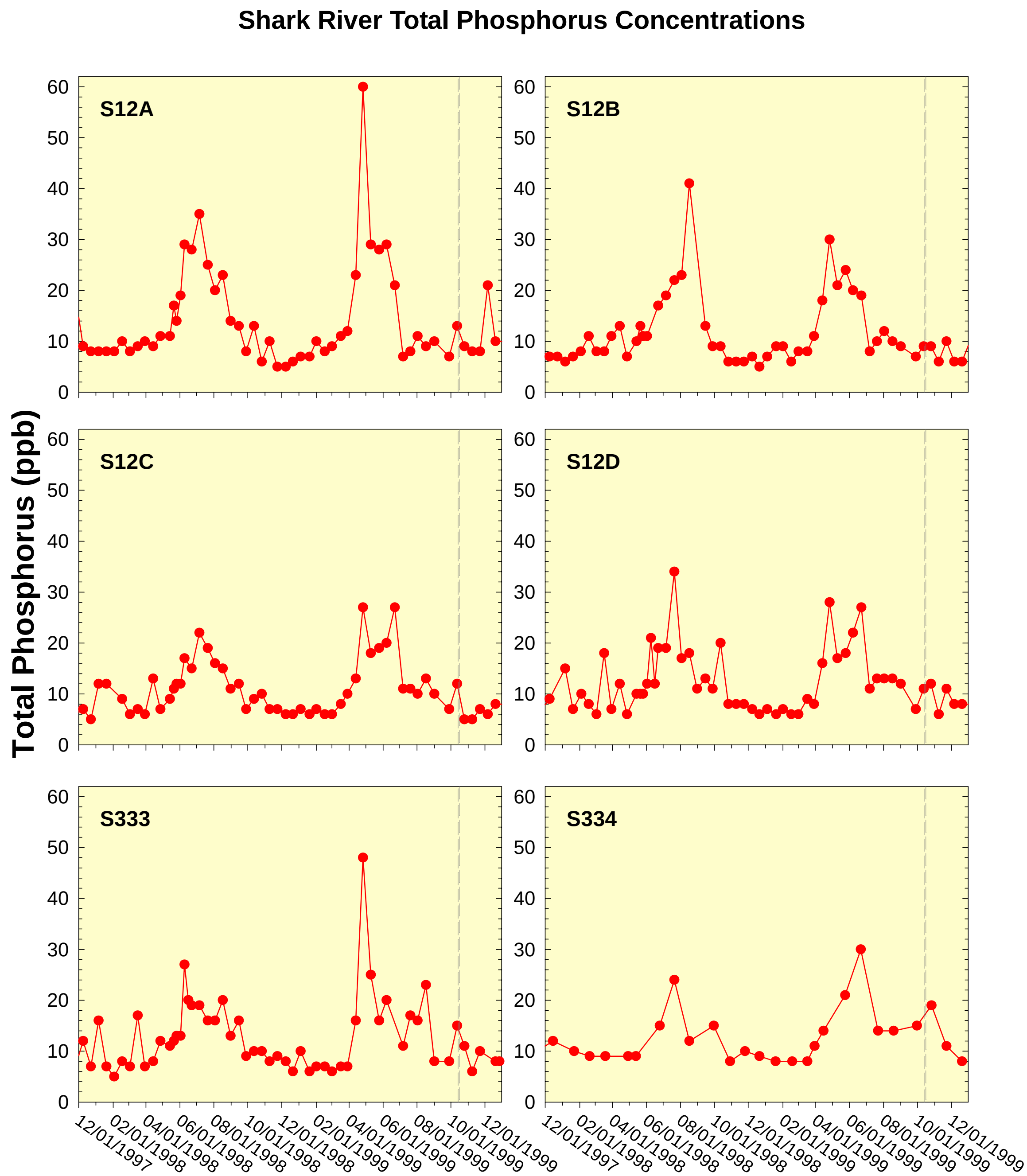


Figure 27. Total phosphorus concentrations for the Shark River Slough structures and S-334. Vertical line indicates the period Hurricane Irene passed through the Everglades National Park on Oct. 16, 1999.

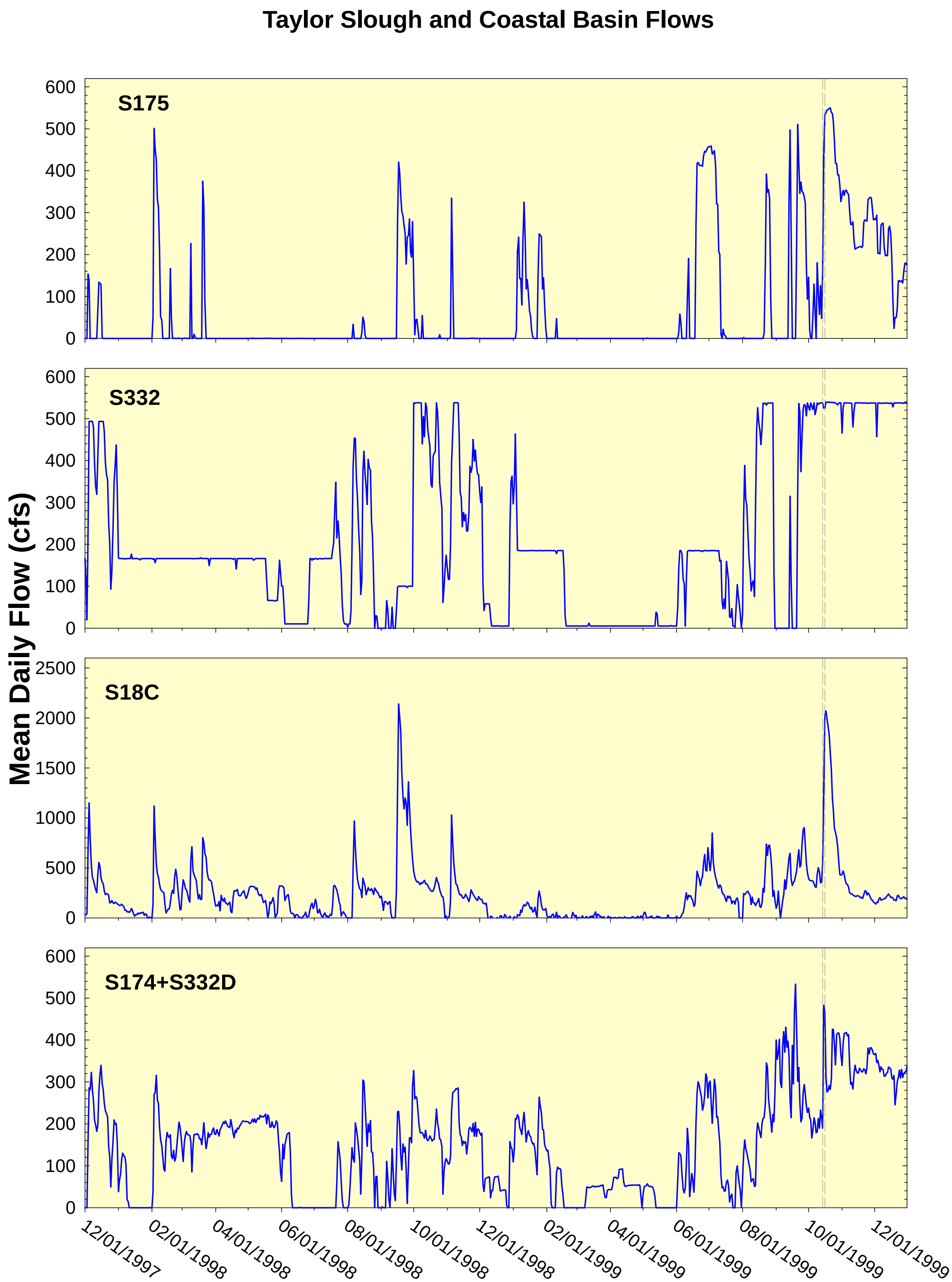


Figure 28. Mean daily flows for the Taylor Slough and coastal basin structures. Vertical line indicates the period Hurricane Irene passed through the Everglades National Park on Oct. 16, 1999.

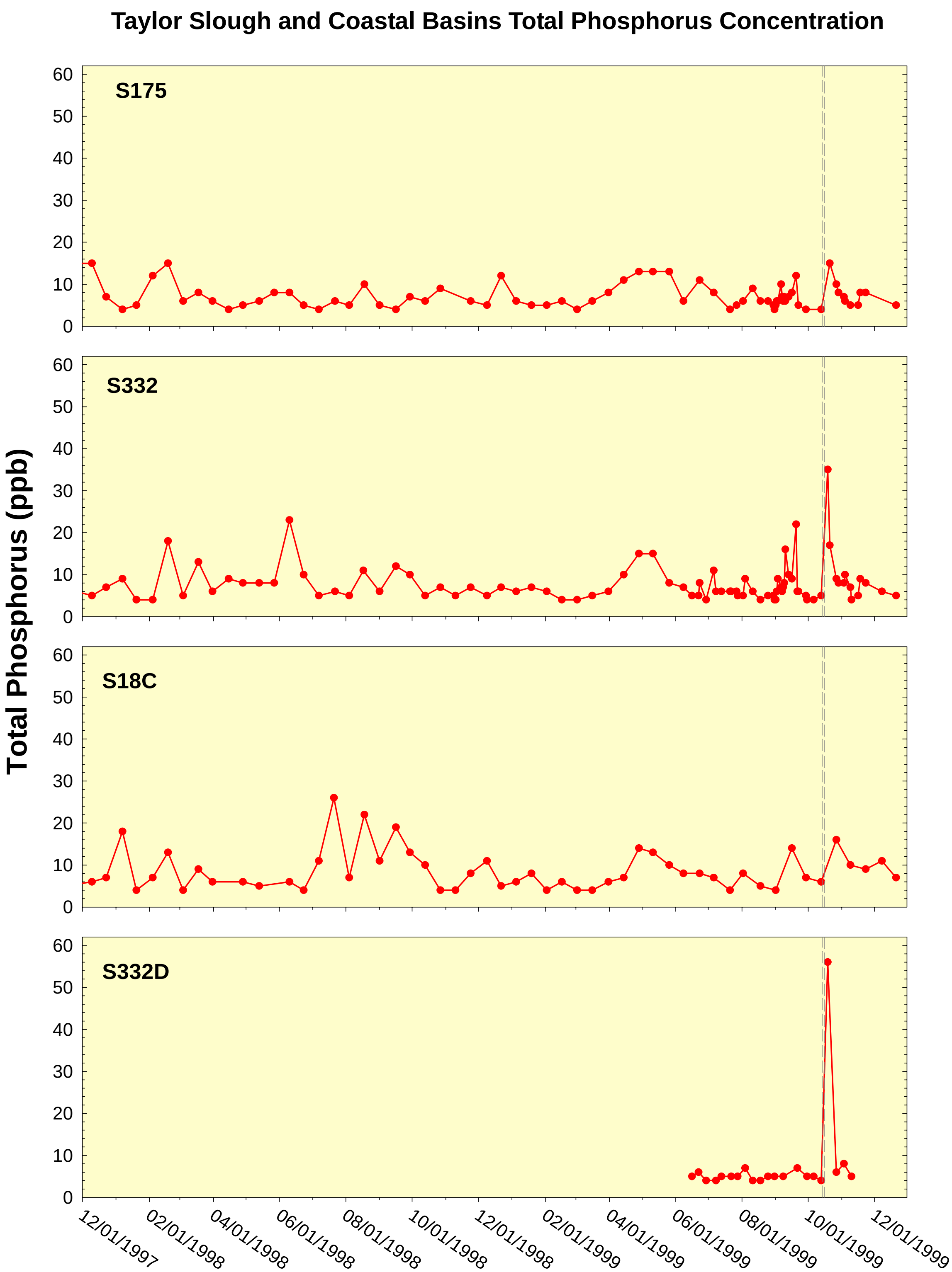
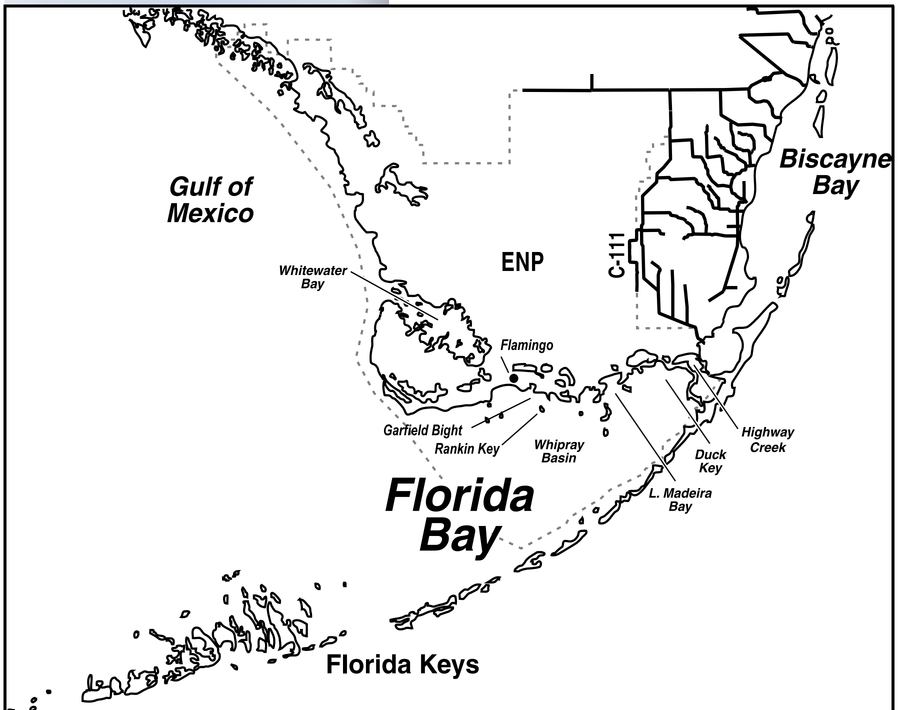


Figure 29. Total phosphorus concentrations for the Taylor Slough and coastal basin structure. The vertical line indicates the period Hurricane Irene passed through the Everglades National Park on Oct. 16, 1999.

Florida Bay



Salinities measured in Florida Bay for the fourth quarter of 1999 averaged 19.7, 20.2 and 20.6 ppt for October, November and December, respectively. As a result of Hurricane Irene, October had the lowest salinities reported for 1999. Higher chlorophyll a *levels (averaging 7 ppb) were observed in October. By December 1999, chlorophyll* a *levels decreased to an average of 2.5 ppb. As in previous reports, lower chlorophyll* a *levels were found in the eastern and southern portions of the bay.*

As part of the Everglades Forever Act, the District, in collaboration with the Everglades National Park and Florida International University, is required to monitor water quality in Florida Bay. Salinity and chlorophyll *a* are used as indicators of water quality within Florida Bay.

Salinity

As an estuary, Florida Bay requires a properly maintained salinity regime for the overall ecological health of the bay. Salinity can be defined as the grams of salt dissolved in a kilogram of water and is expressed in units of parts per thousand (ppt). Within the bay, salinity is affected by freshwater input, in the form of rainfall and surface water runoff from the Everglades, and transport of seawater into the bay predominantly from the Gulf of Mexico. Because the bay is a shallow and wide lagoon, evaporation also affects salinity levels. When evaporation exceeds freshwater input, portions of the bay can become hypersaline. Water conditions in the bay are considered hypersaline when salinity exceeds 35 ppt, which is the approximate mean salinity of ocean water. The central portion of the bay contains small basins surrounded by shallow seagrass banks that extend toward the western edge of Florida Bay. Because of the bathymetry of this region, it is especially susceptible to hypersaline conditions.

In **Figure 30**, the historical (1991 - 1998) mean and range of salinity values at nine monitoring stations in Florida Bay are compared with their monthly mean salinity values for 1999. Stations were selected for this comparison along a west to east transect to depict salinity changes with lateral distance from the western boundary of the ENP (i.e., Gulf of Mexico) to the eastern boundaries of Florida Bay.

Only three stations (Murray Key, Garfield Bight and Whipray Basin) had salinity values outside the historical range (**Figure 30**). In all three cases the salinities were below the historical minimum value and were measured after Oct.14, 1999, when Hurricane Irene passed through the region. Approximately 7 to 8 inches of rain associated with the hurricane fell within the southern boundaries of the district. Coincidentally, the October monitoring event in Florida Bay occurred approximately 10 days after the passage of the hurricane.

Maps showing salinity contours within Florida Bay from October through December 1999 are depicted in **Figures 31a**, **31b** and **31c**. Overall, salinity in Florida Bay during the fourth quarter of 1999 ranged from 0.2 to 33.2 ppt.

During the last quarter of 1999, salinity in Florida Bay never exceeded 35 ppt with values generally below 30 ppt. Bay-wide salinity averaged 19.7, 20.2 and 20.6 ppt for October, November and December, respectively. The lowest salinities in 1999 were measured during the October monitoring event and coincided with the heavy freshwater input resulting from the Hurricane Irene storm event.

Salinity levels measured over the last five years at monitoring sites in Highway Creek, Duck Key, Little Madeira Bay and Whipray Basin are presented as **Figure 32**. A summary of salinities recorded at these monitoring sites for the fourth quarter of 1999 is also presented in **Table 7**. In general, salinities measured during the last quarter of 1999 were among the lowest reported for the past five years (**Figure 32**). Salinities at two of the monitoring stations (Highway Creek and Whipray Basin) increased from October through December while salinity at Duck Key decreased slightly (**Table 7**). However, salinity at Little Madeira Bay decreased throughout the last quarter of 1999 (**Figure 32**). This observed decrease is attributed to an increase in stormwater from Hurricane Irene draining into the bay through Taylor Slough.

Table 7. Salinity (ppt)

	Oct-99	Nov-99	Dec-99
Highway Creek	0.2	5.3	5.9
Duck Key	20.7	18.9	20.1
L. Madeira Bay	16.0	14.9	11.8
Whipray Basin	20.0	23.0	24.8

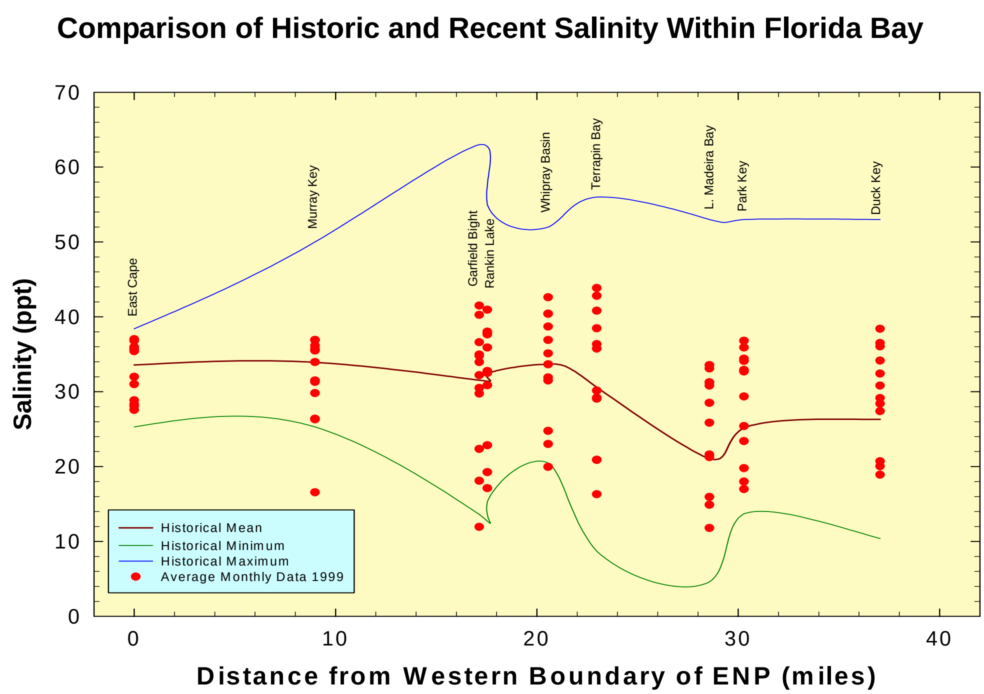


Figure 30. Comparison of historic salinity (1991-1998) with monthly means measured in 1999 at nine monitoring stations in Florida Bay along a west to east transect.

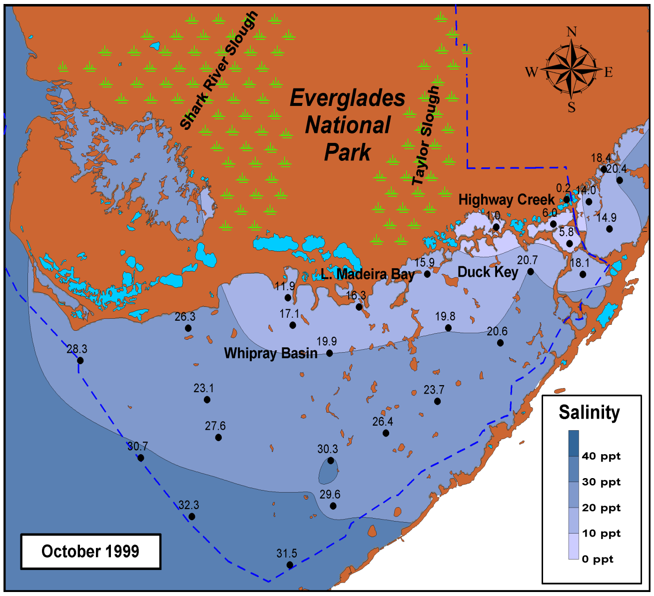


Figure 31a.
Salinity in Florida Bay and waters along the western coast of the Everglades National Park for October 1999. (Data collected by Florida International University.)

Figure 31b.
Salinity in Florida Bay and waters along the western coast of the Everglades National Park for November 1999. (Data collected by Florida International University.)

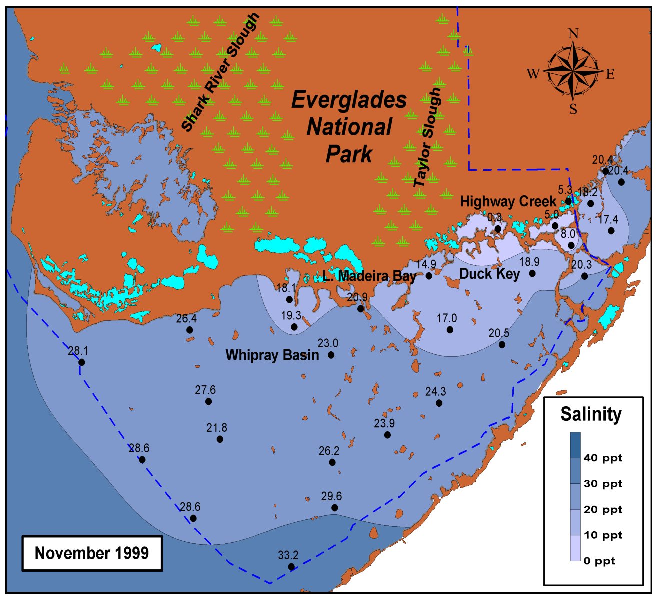
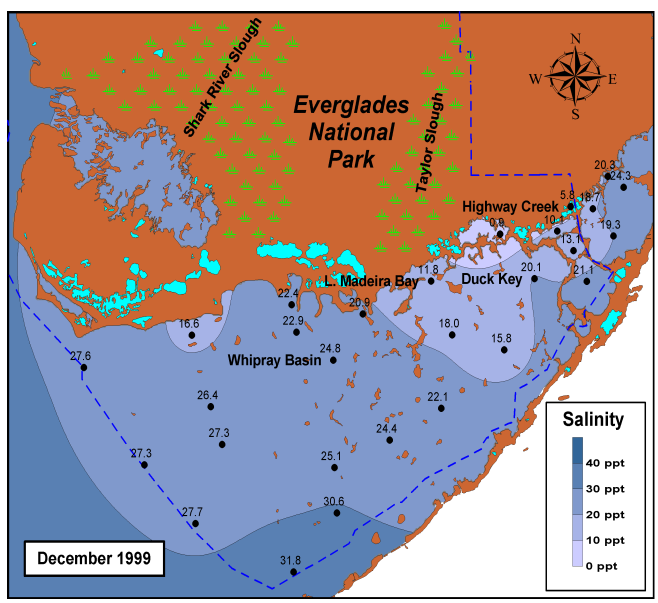


Figure 31c.
Salinity in Florida Bay and waters along the western coast of the Everglades National Park for December 1999. (Data collected by Florida International University.)



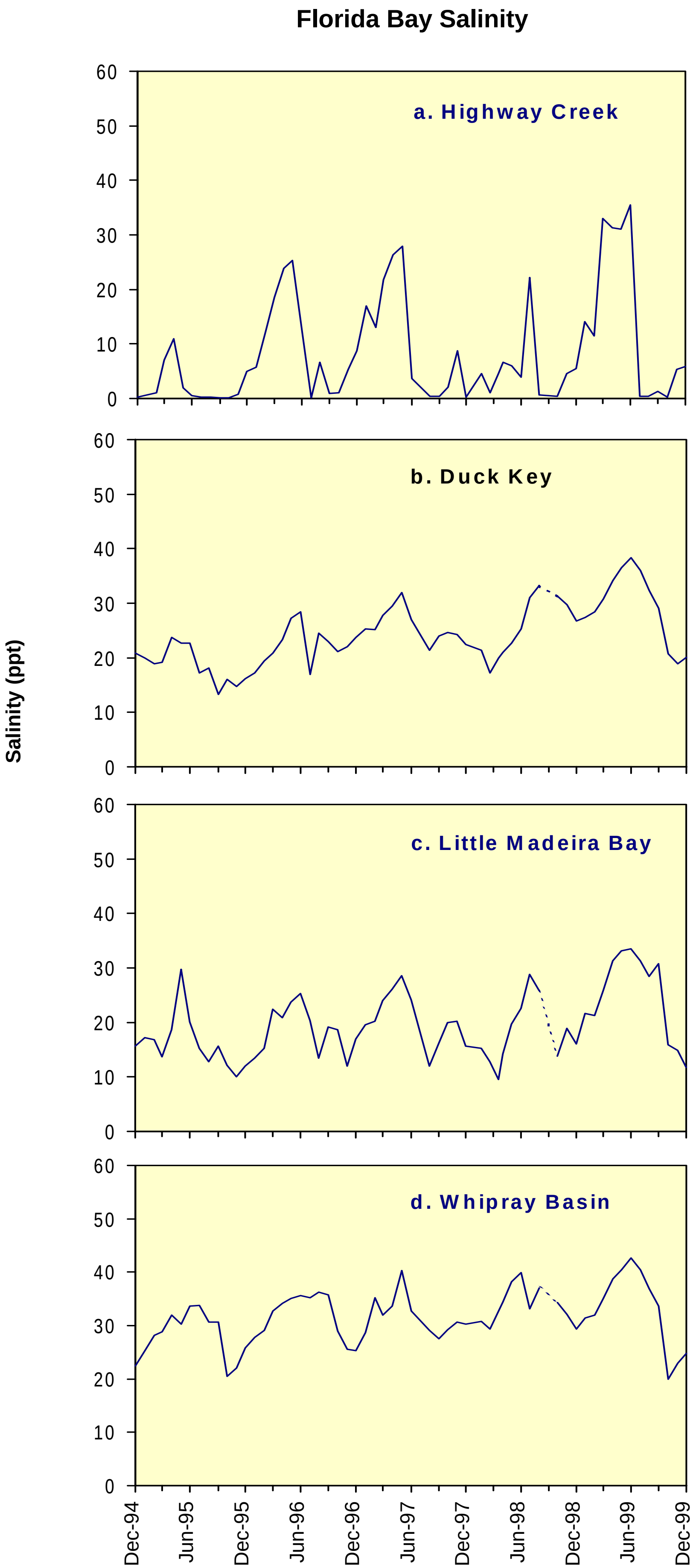


Figure 32.
Salinity at four sites in Florida Bay from Dec. 1,1994, through Dec. 30, 1999. Data are from individual grab samples collected monthly (dashed line indicates missing data).

Chlorophyll *a* Concentrations

Large areas of dense algal communities can affect the overall health of the Florida Bay ecosystem. Chlorophyll *a* concentrations measured in the bay are an indicator of algae (phytoplankton) biomass. Regional chlorophyll *a* concentrations in Florida Bay and the west coast of the Everglades National Park are collected monthly. The distributions of chlorophyll *a* levels measured in the bay during the last three months of 1999 are shown in **Figure 33a** through **31c**.

During the fourth quarter of 1999, mean chlorophyll *a* concentrations in Florida Bay were four times greater than for the rest of 1999. Additionally, mean chlorophyll *a* concentrations throughout the bay decreased from 7 ppb in October to 2.5 ppb in December. The highest chlorophyll *a* levels were observed at Garfield Bight and Rankin Basin (both areas are located directly northwest of Whipray Basin) during the October monitoring event (**Figure 33a**). These elevated chlorophyll *a* levels may be attributed to nutrient inputs to the bay from runoff as well as turbulent mixing caused by the passage of Hurricane Irene along the western portion of the bay. The eastern and southern portions of Florida Bay had lower chlorophyll *a* levels, as previously observed.

Chlorophyll a concentrations measured at four sampling stations in Florida Bay over the past five years of monitoring are shown in **Figure 34**. In addition, **Table 8** summarizes these chlorophyll *a* concentrations from October through December 1999. In general, chlorophyll *a* levels at these monitoring sites were higher during the fourth quarter of 1999 than during previous quarters. The highest increase was observed in October 1999 at the Whipray Basin site where the concentration peaked at approximately 14 ppb (**Figure 34**). By December 1990, the chlorophyll *a* level at this site decreased to 3.7 ppb (**Table 8**). Chlorophyll *a* levels for Duck Key and Highway Creek decreased. Little Madeira Bay had an increase in chlorophyll *a* levels during the fourth quarter of 1999 (**Table 8**). The observed increase in chlorophyll *a* levels at this site may be attributed to nutrient input from stormwater runoff, as well as nutrients released from the sediments due to resuspension.

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Table 8. Chlorophyll *a* concentrations (ppb)

	Oct-99	Nov-99	Dec-99
Highway Creek	0.8	0.6	0.4
Duck Key	0.7	1.8	0.5
L. Madeira Bay	1.6	2.4	2.6
Whipray Basin	13.7	5.9	3.7

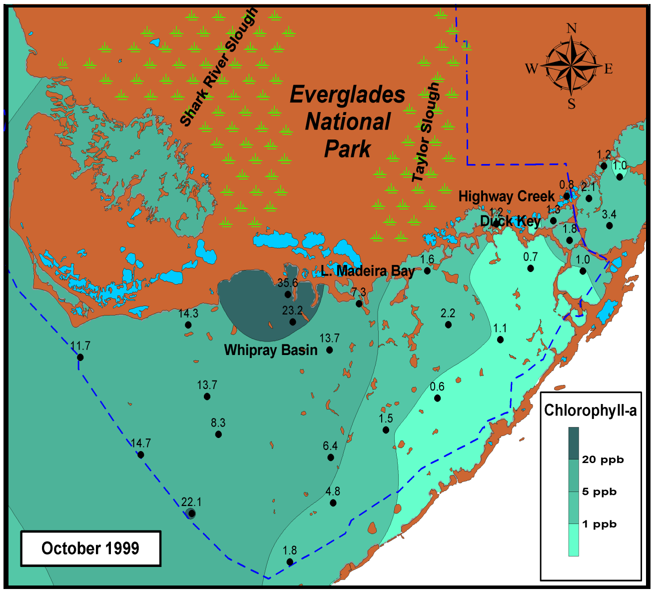


Figure 33a.
Concentrations of chlorophyll *a* in Florida Bay and waters along the western coast of the Everglades National Park for July 1999. (Data collected by Florida International University.)

Figure 33b.
Concentrations of chlorophyll *a* in Florida Bay and waters along the western coast of the Everglades National Park for November 1999. (Data collected by Florida International University.)

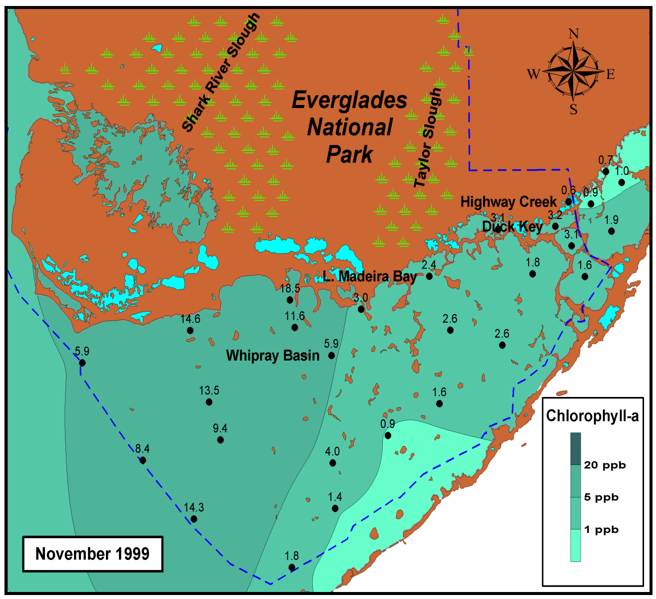
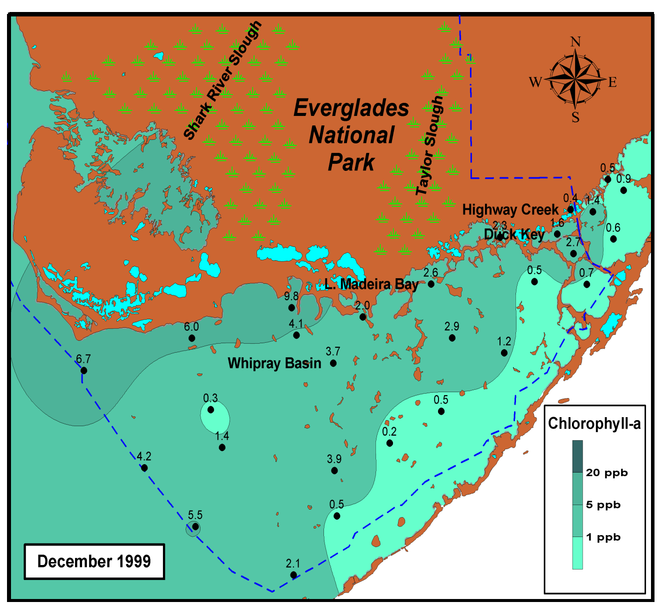


Figure 33c.
Concentrations of chlorophyll *a* in Florida Bay and waters along the western coast of the Everglades National Park for December 1999. (Data collected by Florida International University.)



Florida Bay Chlorophyll *a* Concentrations

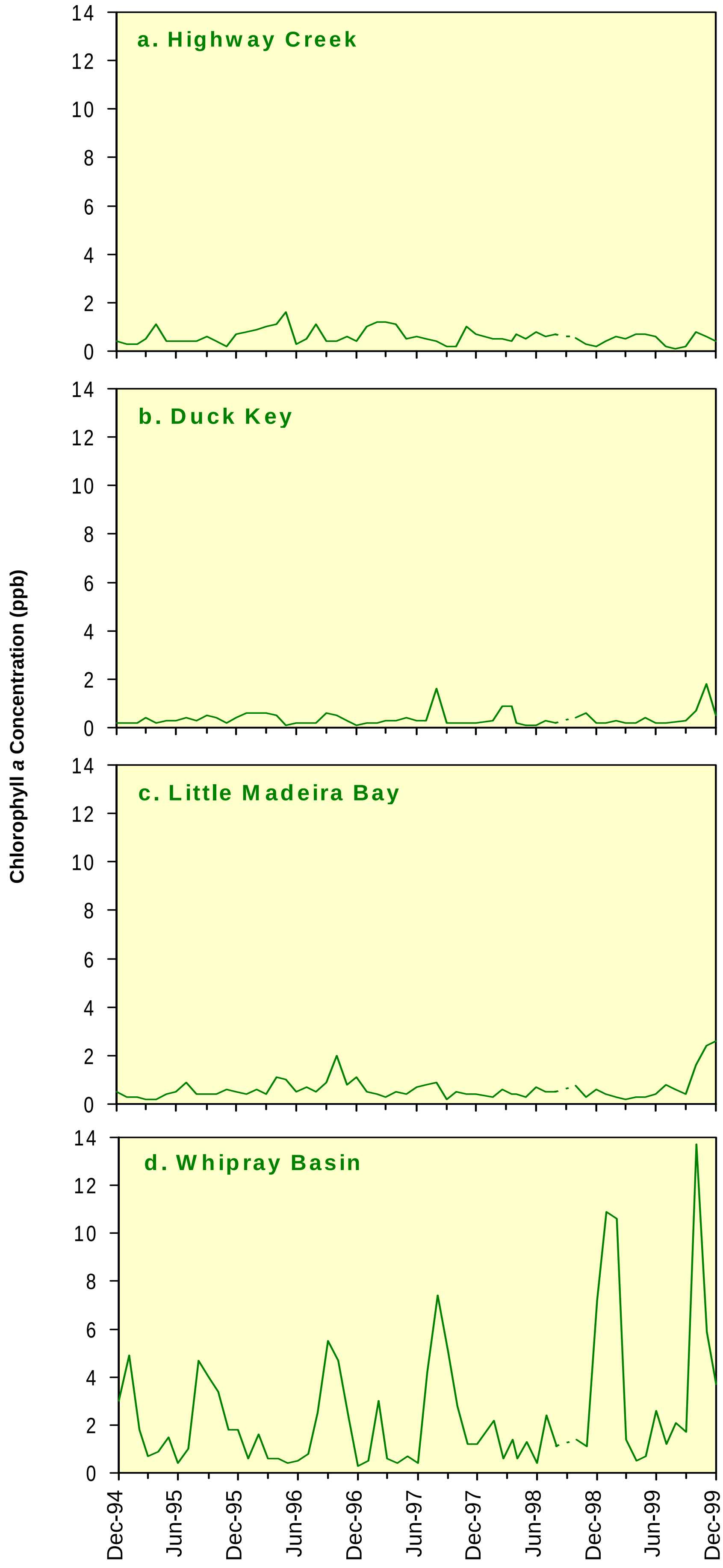
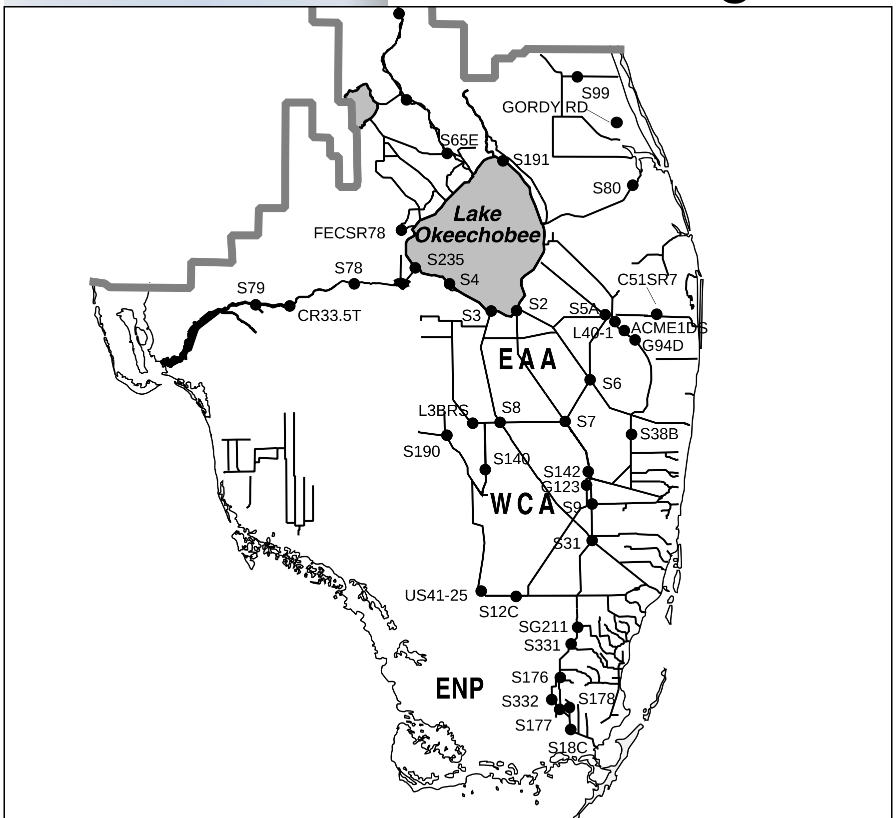


Figure 34.
Chlorophyll *a* concentrations at four sites in Florida Bay from Dec. 1, 1994, through Dec. 30, 1999. Data are from individual grab samples which are collected monthly.

Pesticide Monitoring Program



At least one pesticide was detected in surface water at 31 of the 37 sites in the monitoring network during the November 1999 sampling event. No pesticide concentrations detected in surface waters during this sampling event exceeded Florida Class III surface water quality standards. However, a surface water sample collected at S-38B had a diazinon concentration that exceeded the calculated chronic toxicity concentration for aquatic macroinvertebrates. One DDT and two DDD sediment concentrations were of a magnitude considered to represent a significant and immediate hazard to aquatic organisms.

Background

As part of the District's quarterly ambient monitoring program, unfiltered water and sediment samples from 37 sites were collected from Nov. 8 -18, 1999, and analyzed for over 60 pesticides and/or products of their degradation. The herbicides ametryn, atrazine, bromacil, hexazinone, metolachlor, metribuzin, norflurazon and simazine, along with the insecticides/degradates atrazine desethyl, atrazine desisopropyl, diazinon, beta endosulfan and endosulfan sulfate were detected in one or more of these surface water samples. Most compounds and concentrations found are typical of those expected in areas of intensive agricultural activity.

The District's pesticide monitoring network includes stations designated in the Everglades National Park Memorandum of Agreement, the Miccosukee Tribe Memorandum of Agreement, the Lake Okeechobee Operating Permit, and the Non-Everglades Construction Project (Non-ECP) permit. Surface waters are sampled quarterly and sediments semiannually.

Surface Water

At least one pesticide was detected in surface water at 31 of the 37 sampling sites (**Table 9**). Each of the compounds has previously been detected in this monitoring program.

The GORDYRD site was added to the monitoring program for this sampling event.

A diazinon concentration of 0.059 mg/L detected in the surface water at S-38B should not have an acute, detrimental impact for fish. However, for aquatic invertebrates, this level is slightly greater than the calculated chronic toxicity of 0.04 mg/L for Daphnia magna, a sensitive indicator species for aquatic macroinvertebrates. At this concentration, long-term exposure can cause impacts to the macroinvertebrate populations, but the pulsed nature of agricultural runoff releases to the canal system precludes drawing any conclusions about long-term average exposures.

Beta endosulfan was only detected in surface water during this sampling event at GORDYRD. The concentration of 0.0034mg/L was lower than the Florida Class III surface water quality standard of 0.056 µg/L.

Sediment

At least one pesticide was detected in sediment at 18 of the 34 sampling sites (**Table 10**).

Sediment samples are not collected at GORDYRD, C-51SR7 and C-R33.5T

Ethion was detected in the sediment at S-99 (4.6 µg/Kg) and S-176 (7.1. µg/Kg). However, no sediment quality assessment guidelines have been developed for ethion.

The herbicides ametryn and bromacil, along with the insecticides/degradates DDD, DDE, DDT, ethion and heptachlor, were found in the sediment at several locations, along with two PCB compounds. Some of the detected sediment concentrations of DDD and DDE are usually associated with the potential for impacting wildlife when compared to coastal sediment quality assessment guidelines. The DDT and two of the DDD detections were of a magnitude considered to represent a significant and immediate hazard to aquatic organisms. There are no corresponding freshwater sediment quality assessment guidelines, however.

The above findings must be considered with the caveat that pesticide concentrations in surface water and sediment may vary significantly with relation to the timing and magnitude of pesticide application, rainfall events, flow control and other factors, and that this was only one sampling event. The possible long-term or chronic toxicity impacts are also reported based on the single sampling event and do not take into account previous monitoring data.

Table 9. Concentrations of Pesticide in Surface Water Samples Collected in November 1999

DATE	SITE	FLOW	COMPOUNDS (µg/L) ametryn	atrazine	atrazine desethyl	atrazine desisopropyl	bromacil	diazinon	beta endosulfan	endosulfan sulfate	hexazinone	metolachlor	metribuzin	norflurazon	simazine	Number of compounds detected at site
11/08/99	S38B	N	-	0.53	0.038 I	-	-	0.059 I	-	-	-	-	-	-	-	3
	S142	N	0.014 I	0.011 I	-	-	-	-	-	-	-	-	-	-	-	2
	G123	N	-	-	-	-	-	-	-	-	-	-	-	-	-	0
	S9	Y	-	0.11	-	-	-	-	-	-	0.019 I	-	-	-	-	2
	S31	N	-	0.021 *	-	-	-	-	-	-	-	-	-	-	-	1
	S12C	Y	-	-	-	-	-	-	-	-	-	-	-	-	-	0
	US4125	Y	-	-	-	-	-	-	-	-	-	-	-	-	-	0
	G211	Y	-	-	-	-	-	-	-	-	-	-	-	-	-	0
11/09/99	S331	Y	-	0.010 I	-	-	-	-	-	-	-	-	-	-	-	1
	S176	N	-	0.044 I	0.0099 I	-	-	-	-	-	-	-	-	-	-	2
	S332	Y	-	0.033 * I	-	-	-	-	-	-	-	-	-	-	-	1
	S177	N	-	0.019 I	-	-	-	-	-	-	-	-	-	-	-	1
	S178	N	-	0.019 I	0.010 I	-	-	-	-	-	-	-	-	-	-	2
	S18C	Y	-	0.018 I	-	-	-	-	-	-	-	-	-	-	-	1
11/15/99	S140	Y	-	-	-	-	-	-	-	-	-	-	-	-	-	0
	S190	Y	-	-	-	-	-	-	-	-	-	-	0.026 I	0.038 I	-	2
	L3BRS	Y	-	0.046 I	-	-	-	-	-	-	-	-	-	0.043 I	-	2
	S8	N	-	0.026 I	-	-	-	-	-	-	-	-	-	-	-	1
	S7	N	-	-	-	-	-	-	-	-	-	-	-	-	-	0
	S6	N	0.058	0.082	-	-	-	-	-	-	0.026 I	-	-	-	-	3
	S5A	N	0.056	0.26	-	-	-	-	-	-	-	0.059 I	-	-	0.028 I	4
11/16/99	GORDYRD	Y	-	-	-	0.014 I	0.14 I	-	0.0034 I	0.024	-	-	-	0.80	0.034 I	6
	S99	Y	-	-	-	-	0.19 I	-	-	-	-	-	-	0.84	0.025 I	3
	S65E	N	-	0.04 I	-	-	-	-	-	-	-	-	-	-	-	1
	S191	N	-	-	-	-	0.15 I	-	-	-	-	-	-	-	-	1
	FECSR78	Y	-	-	-	-	-	-	-	-	0.034 I	-	-	-	-	1
	S78	Y	-	0.061	0.01 I	-	-	-	-	-	-	-	-	-	-	2
	CR33.5T	Y	-	0.070	0.013 I	-	0.11 I	-	-	-	-	-	-	0.030 I	-	4
	S79	Y	-	0.065	0.013 I	-	0.070 I	-	-	-	-	-	-	0.035 I	-	4
11/17/99	S235	R	0.010 I	0.072	0.015 I	-	-	-	-	-	-	-	-	-	-	3
	S4	N	0.014	0.12	-	-	-	-	-	-	0.023 I	-	-	-	-	3
	S3	N	0.029 * I	0.12 *	0.014 * I	-	-	-	-	-	-	-	-	-	-	3
	S2	N	0.022 I	0.11	0.022 I	-	-	-	-	-	-	-	-	-	-	3
	S80	Y	0.0097 I	0.13	0.027 I	-	-	-	-	-	-	-	-	0.051 I	-	4
11/18/99	G94D	Y	0.039 I	0.037 I	-	-	-	-	-	-	-	-	-	-	-	2
	ACME1DS	Y	0.055	0.040 I	-	-	-	-	-	-	0.037 I	-	-	-	-	3
	C51SR7	Y	0.048	0.21	-	-	-	-	-	-	-	-	-	-	-	2
Total number of compound detections			11	26	10	1	5	1	1	1	5	1	1	7	3	

N – no Y – yes R – reverse - denotes that the result is below the MDL; * - results are the average of duplicate samples; I - value reported is less than the minimum quantitation limit, and greater than or equal to the minimum detection limit

Table 10. Concentrations of Pesticide in Sediment Samples Collected in November 1999.

DATE	SITE	FLOW	COMPOUNDS (µg/Kg) ametryn	bromacil	DDD	DDE	DDT	ethion	heptachlor	PCB1254	PCB1260	Number of compounds detected at site
11/08/99	S38B	N	-	43 I	-	-	-	-	-	-	-	1
	S142	N	-	-	-	9.3	-	-	-	-	-	1
	S31	N	-	-	-	5.3 * I	-	-	-	-	-	1
	US41-25	Y	-	-	-	-	-	-	1.9 I	-	-	1
11/09/99	S331	Y	-	-	-	1.7 I	-	-	-	-	-	1
	S176	N	-	57 I	-	2.1 I	-	7.1 I	-	-	-	3
	S177	N	-	-	2.7 I	22	-	-	-	-	-	2
	S178	N	-	130 I	-	67	-	-	-	-	-	2
11/15/99	S8	N	4.6 I	-	-	4.5 I	-	-	-	-	-	2
	S7	N	23.5 * I	-	3.0 * I	8.65 *	-	-	-	-	94.5 *	4
	S6	N	9.8 I	-	15	43	10 I	-	-	-	-	4
	S5A	N	3.5 I	-	5.8 I	16	-	-	-	-	-	3
11/16/99	S99	Y	-	-	-	8.4	-	4.6 I	-	-	-	2
	S79	Y	-	-	-	14 I	-	-	-	-	-	1
11/17/99	S4	N	17 I	-	-	11	-	-	-	-	-	2
	S3	N	-	-	2.2 * I	7.45*	-	-	-	-	-	2
	S2	N	12 I	-	9.4 I	37	-	-	-	-	-	3
	S80	Y	-	-	-	-	-	-	-	620	-	1
Total number of compound detections			6	3	6	15	1	2	1	1	1	

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GLOSSARY

12-month moving average

The mean (arithmetic average) of data from 12 consecutive months. As the latest month is added to the data set, the earliest month is dropped from the data set

5-year moving average

The mean (arithmetic average) of data from 5 consecutive annual averages of sums. When the latest year is added to the data set the earliest year is dropped from the data set.

flow-weighted mean

The arithmetic average adjusted for flow:

$$\bar{x} = \frac{\left(\sum_{i=1}^{i=n} q_i c_i\right)}{\left(\sum_{i=1}^{i=n} q_i\right)}$$

q = flow
c = concentration

geometric means

The nth root of individual data values that have been multiplied:

$$G = \sqrt[n]{x_1 x_2 \ldots x_n}$$

EC_{50}

A concentration necessary for 50 percent of the aquatic species tested to exhibit a toxic effect short of mortality within a short exposure period, usually 24 to 96 hours.

units of concentration measurement

(assuming density of water = 1.0)

grams/kilograms(g/kg)=1 part /thousand(ppt)
milligram/Liter(mg/L)=1 part/million(ppm)
microgram/Liter(µg/L)=1 part/billion(ppb)
nanogram/Liter(ng/L)

WATER QUALITY CONDITIONS QUARTERLY REPORT

SOUTH FLORIDA WATER MANAGEMENT DISTRICT

ENVIRONMENTAL MONITORING AND ASSESSMENT DEPARTMENT

APRIL 2000

FOR MORE INFORMATION

C O N T A C T

Thomas D. Fontaine
Environmental Monitoring and
Assessment Department
South Florida Water Management District
3301 Gun Club Road
P.O. Box 24680
West Palm Beach, FL 33416-4680